Aalto University
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EDUCATING THE FUTURE PRODUCT DESIGNERS - EXPLORING THE ANATOMY OF A PROJECT-BASED CAPSTONE COURSE AT AALTO UNIVERSITY

Master's thesis for the degree of Master of Science in Technology submitted for inspection, Espoo, 02.04 2015.

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Abstract of master's thesis

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Abstract **In today´s world design challenges are more complex than ever before. When educating future product designers the aim is to provide them with possibilities to learn the appropriate skills for tackling wicked design challenges. *Product Development Project* in Aalto University is a capstone course in product development that provides such an opportunity in an interdisciplinary team-based real-life design challenge setting. The course takes place at the Aalto Design Factory environment, an experimental platform for education research and application of product development.**

In this thesis professional skills and expertise of a product designer are compared with the intended learning outcomes and student experiences of the Product Development Project for future development of the course. In practice this is achieved through a state-of-the-art literature review, establishing the existing intended learning outcomes and conducting student interviews. The results indicate that the course provides an opportunity to learn important general professional skills and also skills related to design expertise. However some future development suggestions for the Product Development Project are brought forth for increasing the impact of the course.

Keywords Product development education, Professional skills, Design expertise, Product Development Project –course,

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Tiivistelmä **Nykyajan suunnitteluhaasteet ovat monimutkaisempia kuin koskaan aikaisemmin. Tulevaisuuden tuotekehittäjien koulutuksessa tavoitteena on tarjota heille mahdollisuuksia oppia tarvittavat taidot näiden haasteiden kohtaamiseksi. *Product Development Project* –kurssi Aalto-yliopistossa on maisterivaiheen kurssi, jossa opiskelija pääsee kokeilemaan monitieteisessä suunnittelutiimissä tudenmukaisen tuotekehityshaasteen ratkaisemista. Kurssi järjestetään Aalto Design Factory –ympäristössä, joka on kokeilualusta opetuksen tutkimiselle ja tuotekehityksen soveltamiselle.**

Tässä diplomityössä tuotekehittäjän tarvitsemia työelämä- ja suunnittelutaitoja verrataan kurssin oppimistavoitteisiin ja opiskelijakokemuksiin kurssin kehittämiseksi. Käytännössä tämä toteutettiin ajankohtaisella kirjallisuuskatsauksella, valottamalla olemassa olevia oppimistavoitteita ja opiskelijahaastatteluilla. Tulokset osoittavat, että kurssi tarjoaa mahdollisuuden tärkeitä työelämätaitoja ja suunnittelutyöhön liittyviä taitoja. Joitain tulevaisuuden kehitysmahdollisuuksia esitellään Product Development Project –kurssille, jotta kurssin vaikuttavuutta voitaisiin vielä tehostaa.

Avainsanat Tuotekehitysopetus, Työelämätaidot, Tuotekehitystaidot, Product Development Project –kurssi

Preface and Acknowledgements

Wow, has it been a journey or what?! And the day is finally here.

´They´ say it´s only a master´s thesis. ´They´ also say that the best master´s thesis is a finished one. They may say so and they may even be right saying so. However for me this has been a journey of a life time. A finishing touch in my studies, naturally, but more than anything else a final touch in understanding that world is full of information and knowledge waiting for being discovered and explored. This journey leaves me hungrier than ever before for exploring and discovering knowledge and bits and pieces of information. I believe that would be the final goal of higher education – the hunger for knowledge?

I got there.

I got there and now I want to know more.

I will never have the right words for saying thank you for all the people who helped me during this journey – in one way or another. Without the support I most definitely would not be here today writing these words – the help that means so much to me has been and still is priceless.

I feel so much gratitude for having such great and incredible people in my life

– family, friends and especially my ADF-family.

Thank you.

What is the biggest take away for me from this journey? I finally know and believe I can. First couple of years of studying in university had me thinking that I must be stupid for struggling with the studies. That thought has stuck with me through the years.

Now finally while doing this thesis I know that is not the case.

Never say, never,

for I once said that learning is not my thing.

Oh, how wrong was I?

Learning is everybody´s thing!

Hugs,

Erika Rautavaara

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Abbreviations

ABET	-	The Accreditation Board for Engineering and Technology
ADF	-	Aalto University Design Factory
ELT	-	Experiential learning theory
DBL	-	Design-based learning
DDF	-	Duoc Design Factory
DF	-	Design Factory
DFGN	-	Design Factory Global Network
Duoc UC	-	Duoc Universidad Católica
DT	-	Design thinking
HSE	-	Helsinki School of Economics
HUT	-	Helsinki University of Technology
PBL	-	Problem-based learning
PDP	-	Product development project – course
PjBL	-	Project-based learning
UIAH	-	University of Art and Design of Helsinki

1 Introduction

The world that we are facing today is growing more complex and there is more technology involved in everyday life than ever before. Alongside with these changes working life and the requirement placed upon engineering and design are not the same as they were before. To accommodate to these changes internationally and nationally adaptations are to be made. Markets that some decades ago were more national are now global and this challenges nations such as Finland. In pursuance of competitiveness in the global markets Finland needs companies and thus employees that are equipped to face the challenges that 21st century has brought to us. This sets new requirements creates for graduates entering the working life.

Graduates from universities are ought to be the tip of the sword who should entail all the skills and characteristics to enter the current working life. The challenge is that as the working life changes rapidly higher education needs to be able to respond these changes and demands to ensure the graduates as high quality education and good employability as possible.

This thesis has been a part of cooperation in which a course concept has been transferred from Aalto University into a Chilean partner institute. The thesis aims to shed light upon skills that expert product designers have and the learning outcomes of capstone product development course in Aalto University for insight what could be further developed and rich description for documentation. Aalto University was fused 2010 from three separate universities in the Helsinki region amid a national university reform. The result in this case was a creation of a university that aims for quality education that combines technology, business and design and thus giving Finland an edge in the global competition.

Aalto University Design Factory, later referred to as ADF, was the first physical manifestation of Aalto University, founded already in 2008, at a time when the university merger was in preparation. In practice ADF is 3000 m^2 of space for all the stakeholders around the university to come together. The goals of ADF are to change the learning culture in the university and to educate world´s best product developers. Product development is in the core of ADF. (Design Factory, Annual Report 2008-2009)

In Aalto University there is a possibility to study product development at the School of Engineering in Mechanical Engineering department. Product development may be taken as a major or a minor. The most central course of the module of product development is a course called Product Development Project, later referred to as PDP. The course has almost 20 year experience of educating product developers and has been growing its popularity within Aalto University in the recent years and is currently organized in the ADF environment.

This study will investigate the PDP –course. The main goal of this thesis is create rich image of the experiences the students of PDP have had through possible learning outcomes. These experiences will be reflected lightly against the working life demands and the indicators of the skills and characteristics of an expert product designer.

1.1 Background and motivation for the thesis

1.1.1 Aalto University

Aalto University has been operating since January 2010 after the Finnish university reform. Aalto University is a result of a fusion of three universities from the Helsinki area. These three universities were Helsinki School of Economics (HSE), Helsinki University of Technology (HUT) and University of Art and Design Helsinki (UIAH), each one a leading top university in their own fields in Finland.

The mission of Aalto University, as stated in the annual report of 2012 (2012) is: internationally to contribute to a better world and nationally "competitiveness and welfare of Finland". In the website of Aalto University it is stated that: "Aalto University works towards a better world through top-quality research, interdisciplinary collaboration, pioneering education, surpassing traditional boundaries and enabling renewal." (Aalto.fi, 2012) In the annual report of 2012 also the common values are stated being the following: passion, freedom, courage, responsibility and integrity. For quality teaching Aalto states that its goal is "to train responsible, independently minded specialists able to see the big picture." (Aalto University - Annual Report, 2012) These statements generate a clear image that Aalto University entails all different disciplines and characteristics that represent product development

Aalto University considers its Factories as core concepts to enhance multidisciplinary cooperation and as such they are implied to be strategic and visionary elements in the university´s existence (Aalto.fi, 2014). The factories host the multidisciplinary communities that provide facilities and support in pursuit of pioneering education bringing.

1.1.2 Aalto University Design Factory

Aalto University Design Factory has been operating since October 2008 as the first physical building of the Aalto University even before Aalto-university started to operate officially as an entity. It is stated today that the mission of ADF is to develop new ways of working and spatial solutions, to enhance interdisciplinary interaction and to develop a passion-based student-centric learning culture for Aalto University. Everything at ADF is stated to be done according open innovation policy and thus all visitors who are interested in ADF are welcomed. (Aaltodesignfactory.fi, 06.03.14)

ADF hosts 3000m^2 of flexible spaces that have been designed to enable and support different activities of its stakeholders. Factory includes teaching spaces, that are flexible in their use, different facilities for prototyping, team working spaces, a library, facilities for researchers, spaces for partner companies and social spaces such as the ´Kafis´ - cafeteria.

ADF hosts and provides spaces to a variety of courses. According to the annual report 2012-2013 (2013) 37 courses were organized at ADF facilities. The single most largest group of the students at ADF is the student body of the PDP –course - 60,5 percentages in the academic year of 2012-2013. Other big student groups are ME310 – course[1] and International Design

[1] ME310, Mechanical Engineering 310, -course is arranged in collaboration with Stanford University and other universities. The course is an intense one academic year long course that is done in international and interdisciplinary teams. Total amount of ECTS is 35 when successfully completed. The course is small as from Aalto University there are only 20 students per year and it is entered via application process. Challenges completed in the course are fuzzy front-end by nature. The final result is a working prototype. (ME310, 2015)

Management –program[2] students. ADF has its own staff to support the different activities held at ADF premises. The staff is closely working with students during the academic year, for example in the machine shop the staff helps students in their prototyping. Another example is the community atmosphere that aims to enhance the interaction in between the researchers and students. Experiences of ADF community members have been documented in Björklund et al. (2011).

1.1.3 Product Development Project -course

The Product Development Project –course (currently under the course code Kon-41.4002) has its root in the 1980´s in the Mechanical engineering department of the former Helsinki University of Technology (HUT). The PDP is an academic study yearlong team-based project course that is aimed for masters´ degree students as a capstone course. Each student team works with a project proposed by a sponsoring company developing some type of a product concept.

The PDP is a course that brings together engineers, designers and business students but is open for students from other fields of studies as well. It has a strong emphasis on hands-on doing, working with real-life projects and team work. Teams are multidisciplinary with an assigned project manager selected from the participating students. PDP is hosted by the ADF environment since its opening. The PDP –course is the specific interest of investigation in this thesis and will be explored more thoroughly in chapter 5.

1.1.4 Duoc UC and Duoc Design Factory

This thesis has been realized align with a project where the writer of this thesis was assisting a Chilean institute Duoc UC as they started the operations of Duoc Design Factory, later referred to as DDF, in collaboration with ADF. The aim of the project was to help DDF to implement its first ever interdisciplinary course for its students during the fall 2013. This course was to a large extend based on the PDP -course and on the environment that ADF provides for such interdisciplinary courses.

Duoc UC was founded in the year 1968 by a group of students from the Pontificia Universidad Católica de Chile and its mission at that time was to educate non-academic professional workers. Quickly it started to provide short educative programs for professions like for example secretaries and gardeners. Finally the university decided to give Duoc its legal autonomy and the foundation Duoc was formed on the 7th of September in the 1973. Objective for Duoc has been ever since to plan and execute educational efforts for non-academic professions, technicians and to train and develop adult professionals. In the year 1981 the changes in the Chilean law created the new basis for three different levels of higher education that are universities, universities of applied sciences and institutes for technical training. Duoc UC fulfils the two latter purposes with two different foundations. (duoc.cl, 2014)

Today Duoc UC (duoc.cl, 2014) has as its mission:

> "*To train people of technical and professional skills with a solid ethical base in the Christian values, who are able to act with success in the work life and who are committed to the development of Chile.*"

[2] International Design Business Management -program has been arranged in Aalto University. It can be taken as a major or a minor. It is based on a project that is an eight month long industry project done in multidisciplinary. The industry project is worth 15 ECTS. (IDBM, 2015)

And vision:

> "*To be the leader of higher technical professional education and that their graduates are the best of the country.*"

Duoc Design Factory was established and launched in the November 2012 as an agreement with Duoc UC and Aalto University. The goal of DDF is to stimulate creativity of its students in order to develop the capabilities, knowledge and attitudes in order to enable the collaboration and interdisciplinary work. The first physical setting of DDF was established at San Joaquín campus of Duoc UC in Santiago de Chile.(Duoc Design Factory, 2014) The first semester that DDF was open it had no courses running yet. During the fall 2013, which was the second whole semester that DDF was running, the first round of the localized version of PDP –course called "Design Factory" was held. The author of this thesis spent two periods of about six weeks during that semester onsite at DDF. The first onsite period was in the beginning of the course and second at the end of the course.

As a whole the course "Design Factory" was the first interdisciplinary course held at Duoc UC. The idea is similar as in PDP –course: to bring together different disciplines to engage in product development on challenges provided by industry. In the first realization of the "Design Factory" –course there were two different sections, each of with roughly 25 students in them. Most of the students were industrial or graphic design students but some were from information technology, marketing and engineering. Students in each section were divided into three different teams. There were two companies providing topics for the teams. Altogether three teams worked with the same topic, but with each team working individually.

During the course classes were held either once or twice a week depending on the section. In total the weekly class working hours were 4 hours but the students were expected to work outside the class hours also, the theoretical total amount of hours spent hitting 72 hours during the semester. The companies that provided the challenges participated once in the beginning and came to see the results in final presentations. There were two teachers, one for each section, both with a design background. In addition to the teachers the author of this thesis was part of the teaching staff. The author´s role was also more coaching the teachers, acting as their reflection partner when possible and trying to build a bridge in between the classical model of a teacher and acting as a coach.

During the time spent in Duoc UC and DDF the author spent doing participatory observations of how the students acted, what might work out in the course and reflecting the teachers´ role to provide input for the further development of the newly established course. These experiences have had influence on the formation of this thesis as a useful resource for further development.

1.1.5 Design Factory Global Network

Design Factory Global Network, later referred to as DFGN, is network that brings together different Design Factories around the world.

> *" Design Factory Global Network is the network of innovation platforms, which drive change in their own institutions for a better learning-culture."*(DFGN Atlas, 2015)

All current DF´s are created to match the interests of the host institution while sharing the same passion for student-centred learning and the hunger for establishing passion-based learning atmosphere. The history of DFGN is closely related to ADF´s history since ADF was also the first DF in the world. This creates a close bond in between DFGN and the PDP –course. DFGN

operates based on the interests of its members and the annual activity is the Design Factory week that has been growing yearly, while student mobility, course collaboration and common interests are another way of doing cooperation between DFGN members.(DFGN Atlas, 2015)

The DFGN has been growing steadily since its start. Figure 1 presents the current status of the DFGN members, concluding at 11 members at the moment (DFGN Atlas, 2015). Implementing a PDP-inspired course or doing collaboration with the PDP –course have been some of the ways to start a DF and that is where this thesis offers value.

This research has been done as part of a project where PDP-inspired course was implemented at the fourth member of DFGN – DDF. That experience of going global with the course –concept through DFGN is in closely related to this thesis. On one hand these reflections and experiences along with the empirical work done in the Chilean context provided input for the development of the PDP -course. On the other hand this thesis aims for providing insights of PDP -course to anybody who is interested in acting in a design factory –way.

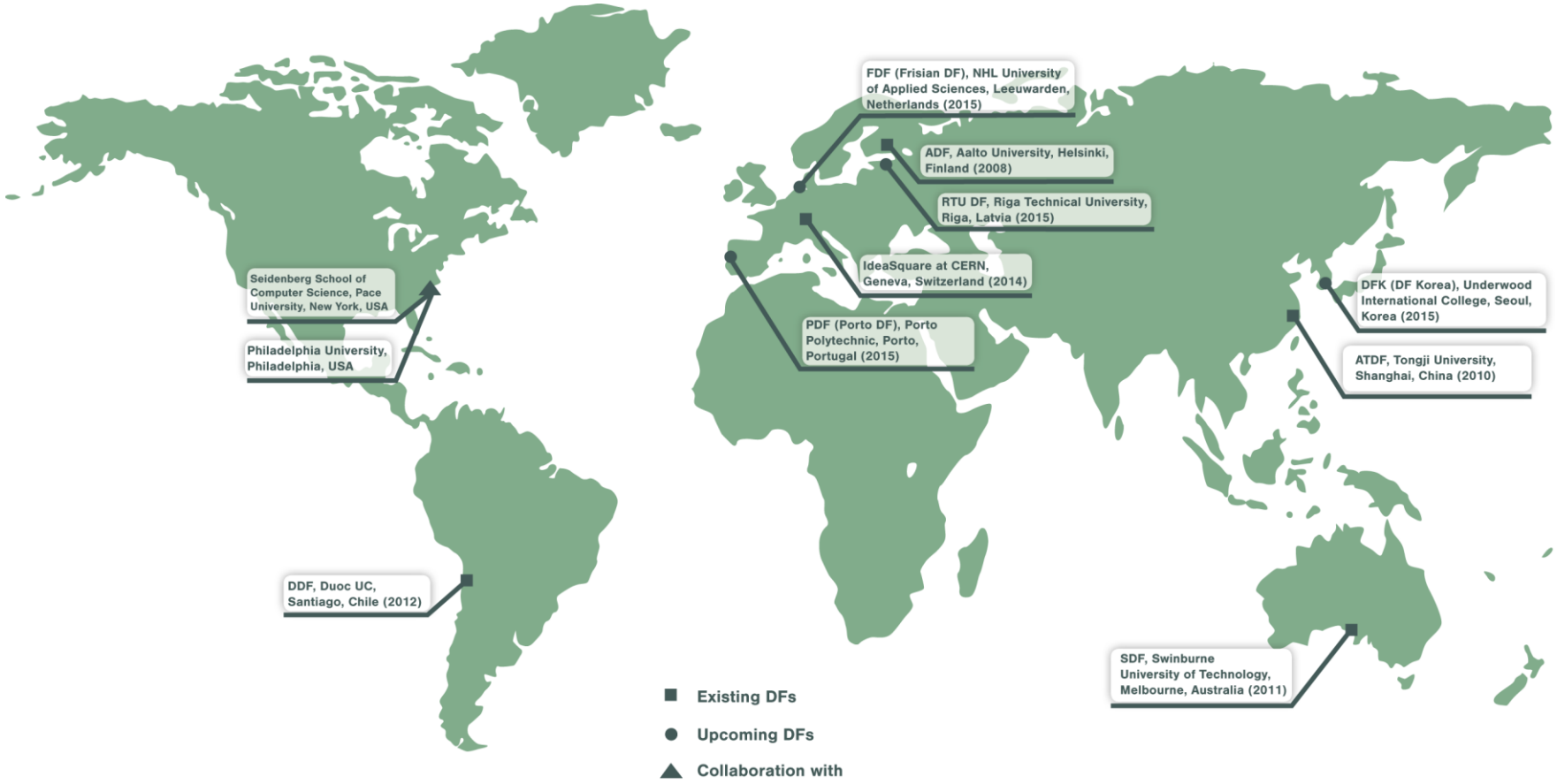

Figure 1 Design Factory Global Network has grown in the resent years rapidly and there are DF´s in almost every continent.

1.2 Thesis scope and objectives

This thesis concerns the education of product developers – or designers. In this thesis the word designer refers to anyone working with designing products, whether they are engineering or industrial designers. There is an interchangeable and overlapping use of product design and product development in the literature (c.f. Lindbeck & Wygant, 1995, Ulrich & Eppinger, 2012, Otto & Wood, 2001). Both terms are used for describing the activities and the people conducting the activities that produce products for markets. Furthermore the word design itself is problematic in the Finnish language as the translation has a double meaning depending on the context. The English word design may be translated to industrial design or to design in more general sense as in engineering design and architectural design. In this thesis the word design used and it is considered as a broad concept of deliberate and professional planning and design process of making a product.

The PDP course has been relatively little studied systematically even though the course has gone through several empirical iterations. The aim of this thesis is to create a rich image of the PDP experience from a student perspective focusing on the learning outcomes and to reflect those against the professional skills and characteristics embodied by expert designers. Based on that broad perspective of this thesis (Corbin & Strauss, 2008, p.10) the research questions are set to be the following:

I. What is the state-of-the-art understanding of the present-day skills and characteristics of an expert product designer?

II. What kind of learning outcomes and skills development from the Product Development Project –course manifests in student retrospectives?

III. What implications do these (RQ1 & RQ2) have for the possible future developments of the Product Development Project –course?

Additional goals for this thesis are to document the course format and to create as extensive and rich description of the student experiences in order to being able to feed in for ideas of development of a possible new PDP -inspired course. As the DF–concept is going global through the DFGN, one of the possible ways of implementing a new design factory is to start holding a similar course as the PDP. Thus there is a need to document the possible essence of the course in one place and to create a wholesome sketch of the course that is used for any future PDP adaptation in different contexts.

In figure 2 the foci and construction of this thesis is presented and investigating these three elements: skills and characteristics of a professional expert designer, intended learning outcomes and learning outcomes of the PDP -course are the core of this thesis.

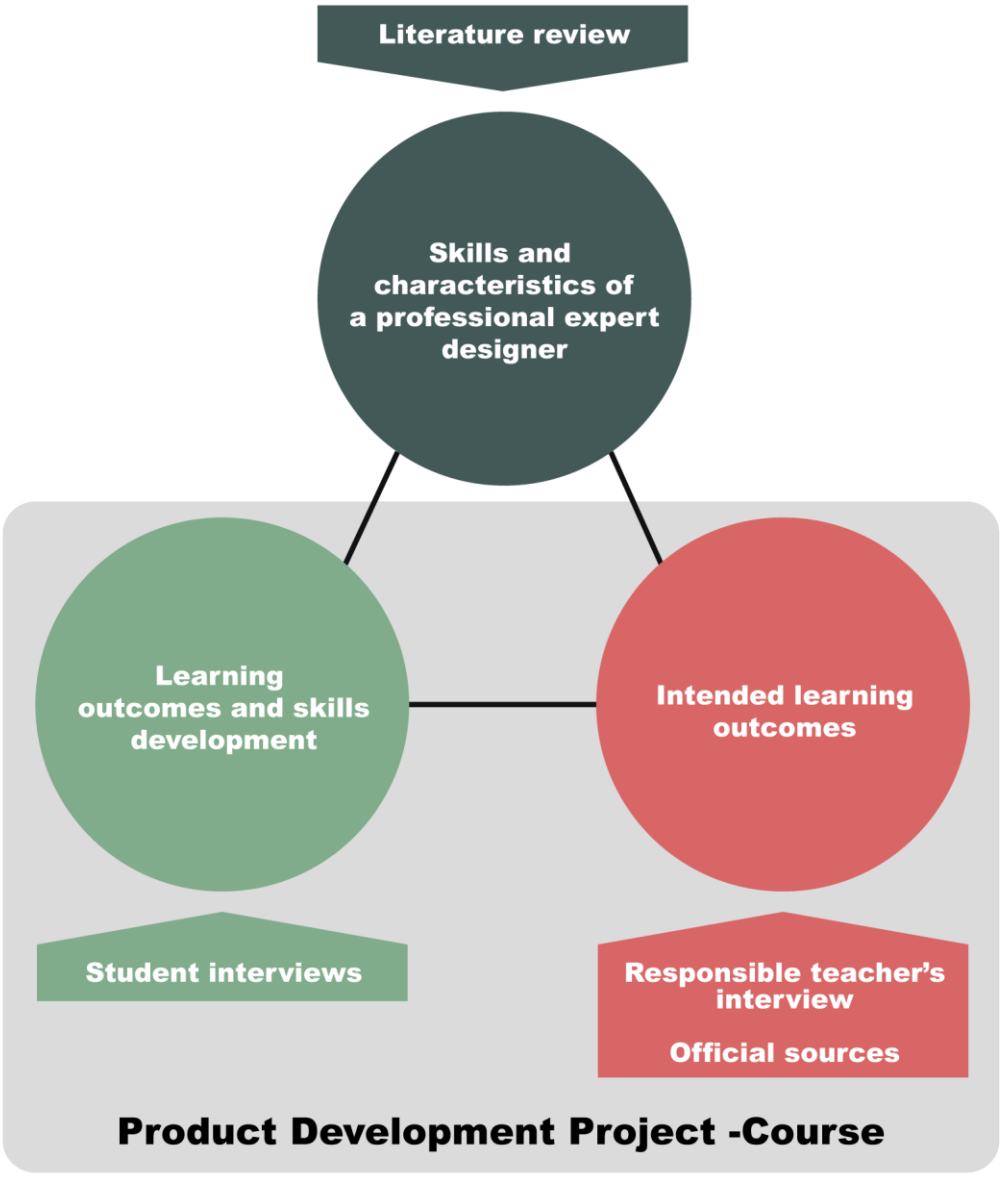

Figure 2 Construction and foci of the thesis.

1.3 Thesis Structure

This thesis has eight chapters. In the first chapter the subject and the context are introduced. In the second chapter the research methods are explained among the process. Literature review is divided into two chapter three and four. Chapter three investigates product design as a field, general professional skills and the skills and characteristics of an expert product designer. Chapter four provides a brief glance of learning and teaching in the design and engineering context. In chapter five the PDP –course is described. Chapter six the results of the interviews and benchmarking are reflected with the literature and suggestion of further development are given. Chapter seven dedicated for discussion and conclusion.

2 Research Methods

The aim of this research is to give as broad documentation of the PDP -course, shed light upon the students´ experiences of the PDP -course and to create a rich and extensive description, the research methods are qualitative. Through qualitative methods the research aims to get the perspective of the participants and create a vision of the issue of interest (Corbin & Strauss, 2008) while understanding why the interviewee has this perspective (King, 2004) and the method includes the interpretation of the researcher as well (Corbin, Strauss, 2008). The qualitative methods enable to explore the interests in a broader sense and different levels (King, 2004). Knowledge claiming philosophy in this thesis and research is that on constructivist for the purpose is to generate some sense and patterns of the experiences of the participants (Creswell, 2003). The research covers aspects of grounded theory methodology (Corbin & Strauss, 2008, Länsisalmi et all., 2004) as the aim is in creating structured information based on the qualitative data gathered. In detail grounded theory attempts to create a theory based on the qualitative data (Länsimäki et all., 2004) It is also thought that the researcher him/herself is an accountable for being "sensitive" during the research process (Corbin & Strauss, 2008) meaning that qualitative research is not thoroughly objective but related to the researcher as well in the data collection and analysing phases. The course has been relatively little studied and thus the research reflects an explorative approach as opposed to validation, there was no reason to do quantitative research for example in form of a questionnaire that could be transformed into statistic data as it was still unclear what phenomena to look for (Creswell, 2003). This research followed the general qualitative research interview process (King, 2004) defining the interest of the research, creating an interview guide – found in the appendices, recruiting participants and carrying out interviews. This research followed the general qualitative research interview process (King, 2004) defining the interest of the research, creating an interview guide – found in the appendices, recruiting participants and carrying out interviews. Theoretical framework was not used and it is arguable whether it is needed in qualitative research (Corbin & Strauss, 2008). The literature collection was done separately for comparison of the interview results.

2.1 A state-of-the-art review of the skills and characteristic of an expert product designer and related teaching concepts

In this thesis the field of design and engineering literature were investigated with an interest on exploring qualities, skills and characteristics of an expert product designer. The literature that mostly consists of academic publications and reports was kept broad as the word design may refer to different contexts. Furthermore the literature review was extended into the related teaching methods, problem-, project- and design-based learning, to briefly describe them. This was done in order to give a broad view what is the idea behind using these methods in this product design context. As there are so many things to consider what a newly graduated product designer ought to know, the focus has been kept closer to engineering education even though not in the disciplinary expertise and the literature is brought from different fields. In order to present a compact and concise overall view of the relevant skills the different listings and depictions of relevant skills were collated for comparison (Corbin & Strauss, 2008).

Additionally teaching concepts that are close to the way the PDP –course is organized are briefly presented. The literature consists of academic publications and reports. The review has

been extended into problem-, project- and design-based learning as concepts and giving a brief look into the term capstone course. The PDP –course is held at the ADF which is different from a conventional learning environment, related issues are presented briefly as well. Teaching and learning aspect has been taken to be part of the course for feeding into the final implications of this research as well as providing a broad review on the matter for the reader.

2.2 Student interviews

Conducting interviews is a good way in qualitative research to gather data (Corbin, Strauss, 2008). The insights of the PDP course were gathered through thematic semi-structured retrospective interviews as it is thought that the more unstructured interview is the more valuable the data is (Corbin, Strauss, 2008). The presumption for the participation in this study is that the participant has completed the PDP –course. As PDP, regarding the learning outcomes, has not been studied before, the interview was created to discover experiences broadly of the course while the interview guide bears the principal assumptions that one has learned something during the course. The responsible professor was also interviewed to explore that point of view. In all of the interviews paper and pencils were provided for visualizing and writing down the thoughts and the interviewees were asked to visualize the process done in their project.

2.2.1 Participants

The student participants had completed the course during the academic year 2012-2013 and the interviews took place within two months after the course had ended. The invitation to the interviews was sent via the course email list. Out of all the approximately 190 students who had completed the course ten took part in the interviews. The participation was voluntary.

In the table 1, information of the interviewees is gathered. There were four different nationalities and the interviews were conducted either in Finnish or English depending on the interviewee. All except one were masters´ level students across different study fields.

Table 1 Information of the student participants.

Student	Field of study - Major	Minor	Master/ Bachelor	Role
S1	Business - entrepreneurship	International design business management	Masters	Team member
S2	Computing and information science	Aalto Ventures program	Masters	Project manager
S3	Information networks	Product development	Masters	Project manager
S4	Mechanical engineering - product development	Work psychology	Masters	Team member
S5	Mathematics	Unknown	Bachelor	Team member
S6	Electrical engineering	Unknown	Masters	Team member
S7	Business - strategy	Information technology	Masters	Team member
S8	Business - management	Corporate communication	Masters	Team member
S9	Mechanical engineering - machine design	Economy	Masters	Team member
S10	Mechanical engineering - machine design	Electronics	Masters	Team member

2.2.2 Data analysis

The interviews lasted between 50 minutes and 70 minutes, averaging at 60 minutes. All the interviews were audio-recorded and transcribed. The analysis was conducted as quantified qualitative thematic as suitable with ´messy verbal data´ (Chi, 1997). The gathered data was segmented into individual arguments. The segments expressing direct and indirect statements regarding what students felt they had learned during the course, what impacted their learning experience and other relevant comments of the course. In total 395 segments were identified. Those segments were then examined for general themes and content coded (Chi, 1997). At times the segments were not clearly identified as one of the categories and thus those segments have been counted into as many categories as they represented. The main topics and themes identified were visualized and interpreted (Chi, 1997). These were lastly lightly compared with the literature review findings (Corbin, Strauss, 2008) for final interpretations and implications.

2.3 Documentation of the PDP -course

As one side goal of this thesis is to be a resource for new upcoming design factories that may want to start their activities based on a similar course as PDP, the documentation of PDP – course is an important factor in this thesis. The data used in this thesis is based on course website, lecture slides, course calendar and other materials published about the course. The interview of the responsible teacher has been also an important source of information for the documentation. The responsible teacher´s interview was conducted four months after the ending the course in academic year 2012-2013. The interview was held in order to get more insight of the course from the responsible teacher´s perspective, as in to avoid any assumptions. The interview lasted 81 minutes and was done in Finnish. All of this is compiled in

a way that is aimed for giving a broad view on how the course is conducted. With the documentation of the course and the student interview results create one interpretation of the course.

2.4 The limitations of the research

The data collection was done two months after the course had ended which is quite a short time for the deep learning outcomes to surface to the consciousness of the interviewees. Thus the interviews are likely not to provide the fully reflected learning outcomes of the course. Methodological disadvantages in qualitative research are that the quality of data collection is dependent of the researcher and the amount of data may overwhelm its researcher. Also the writer has close connections to the course as being a participant in the course as a project manager in one team during the same academic year of 2012-2013 as the data collection was done which could cause bias in the interpretation of the data. However, the length of this process has given more time to have a neutral and objective perspective on the data. Even though in the qualitative research the researcher her/himself is an important ´tool´ (Corbin &Strauss, 2008), the longer period may have given a better sensitivity to the data analysis. Also the quantified analysis is used in order to enhance the transparency and reliability of the interpretation (Chi, 1997). Any statistical conclusions cannot be made due to the small data sample and thus the results are not generalizable. The PDP -course is interdisciplinary by nature and some of the skills and characteristics of an expert product designer are not discipline related, the point of view taken here is that of engineering due to the background of the writer.

3 Skills and capabilities of a professional product designer

Designing is not a sole privilege for professional designers, it is an action that every human being does. In the words of Nigel Cross (2011) *"Everyone can – and does – design."* Whether it is a conscious or an unconscious action, it is natural to us on a daily basis. However when contextualizing design as a professional action specifically product design more constrains of practices can be found (Lawson & Dorst, 2009) in order to solve product design challenges.

As the worlds is changing faster than ever before this seems to have lead into the situation where the domain specific knowledge is faster outdated and the generic skills more lasting (c.f. McQuaid, Lindsey, 2005). Therefore professional skills have gained more attention and discussion in the recent years. In this chapter the factors and skills for expertise and professional product designers are explored from literature. First in the part 3.1 professional skills will be looked into from a variety of sources and then a concept of employability is added for constructing a holistic image of necessary skills of a professional.

The next part 3.2 in this chapter takes a look into the design expertise shedding light upon the field of product design and the skills mastered by expert designers. Product design is based heavily on cognitive actions and is considered to be knowledge work, in which different disciplines are combined aiming for a shared goal – a successful product (Cross, 2011, Lawson & Dorst, 2009). Often the project setting is ambiguous and the means for reaching the final destination with the best possible outcome is reached through a shared act and understanding (Cross, 2011, Lawson & Dorst, 2009). In that journey of designing product all the experts from different fields are equally important for the success (Lawson & Dorst, 2009).

The goal of this chapter is to provide an image of a professional expert designer and what skills they master and what characteristics are shared by them. It ought to be noted that the transition from a novice designer into an expert designer is not thoroughly explores and doubtfully it is the same for all.

3.1 Professional skills

In Finland by law universities aim to educate their students to serve the country and humanity (Ministry of Justice, 2014). Ideally that would be a smooth and fast transition from being a student into an active employee equipped with up to date skills and knowledge. The world we are living in requires new skills and knowledge to be adapted constantly (Seely Brown & Adler, 2008). The increasing global discussion brings up the rising challenge that employers do not seem satisfied with the graduates by several authors (c.f Crawley et al., 2007) and for example in the UK graduates may struggle getting a smooth transition from university into working life (Tomlinson, 2007). Non-domain specific professional skills bear an effect also on the employability of graduates (McQuaid & Lindsey, 2005). In this light it is crucial for that universities pay attention also to those skills meanwhile educating the domain-specific skills to their students.

It can be argued that the courses a student takes are intended for accumulating knowledge and skills. The increase of knowledge and skills ought to enhance the "employability" and the

readiness to enter the working life. Thus it could be stated that the intention of each course is to make a student more employable. Nonetheless not all the courses in the curriculum aim to provide same skills. Some courses may be more focused on the disciplinary content and other courses may be more focused on the complementary skills. The entity that universities provide for their graduates is the whole curriculum. Completing the whole curriculum a graduate should then be ready for working life being the equipped with necessary professional skills.

Professional skills, soft skills or working life skills – depending on the source in which term is used (c.f. Lee, 2003, Shuman et al., 2005). In this thesis the term professional skills has been chosen and it refers to skills that are not domain specific skills but rather skills that any graduate would need in their future jobs no matter the domain. Professional skills do not include domain-specific skill, also called basic knowledge (Christiaans, Venselaar, 2005), such as for example calculus in engineering. It has been noted that graduate engineers do not only need strong domain-specific skills but also professional skills for surviving in the working life (c.f. Shuman et al., 2005). This goes especially well with product designers who, when designing a product, need to take into account the other disciplines (Cross, 2011, Lawson & Dorst, 2009).There seems to be a gap in between skills provided during university education and requirements set by work life (Tynjälä, 2008).

In order to attend this gap the skills need to be identified first. For mapping different professional skill different sources have been explored in the result can be seen in the table 2. The sources vary from notable, e.g. ABET (Accreditation Board for Engineering and Technology) to single articles and studies in order to give as wide perspective as possible from various points-of-views. The goal of the table 2 is to create a cross-cut view of what are seen as important professional skills across different kind of sources. The professional skills have been organized in order to establish an understanding what are seen as important ones. The table 2 is thus divided into categories that represent different main themes for clearance. Some of the sources (c.f. Shuman et al.2005, Crawley et al., 2007, ENAEE, 2007) have included skills and competencies that are not the main interest in this thesis as they represent the ´hard and domain-specific skills´ of engineering. Those skills will be overlooked in this thesis and thus are not shown in table 2.

It is easily observed that the same skills are identified by most of the sources and based on that a general conclusion is presented here that the professional skills are: personal skills, team working skills and communication skills. Graduates seem to value the same skills (c.f. Davis et al., 2012, Creber et al., 2007). There are couple of less recognized skills based on table 2 that are ´life-long learning´ and knowledge & information management. The latter may be argued to be either domain-specific or general skills as life-long learning is clearly not domain specific.

Table 2 A compilation of professional skills.

	ABET (Shuman et al., 2005)	Crawley et al., 2007	Hesketh A., 2000	Fry et al., 2004	ENAEE, 2007	Crebert et al., 2004	Grant & Dickson, 2006	Musa et al., 2012
Personal skills			Self-management	Personal skills	Transferable skills		Self-management	Responsibility, self-confidence, good work attitude, self-motivation, self-management
Team work	An ability to function on multidisciplinary teams	Work efficiently as a team	Team work	People skills	Transferable skills	Team working skills	Ability to work in teams	Social skills, team-spiritedness
Communication	An ability to communicate effectively	Communicate effectively	Communication, oral Communication, written	Communication skills Use of modern communcation and information technologies	transferable skills	Communication	Communication in different forms: written, oral etc.	Communication skills
Project management		Management skills Project management methods						
Data and information	An ability to design and conduct experiments, as well as to analyse and interpret data	Analyse information Gather information		Information management skills IT	Engineering analysis Knowledge and understanding	Analysis		
Learning	A recognition of the need for and ability to engage in life-long learning	Self-learning	Learning					

Alongside with these professional skills a larger concept of employability presented by McQuaid and Lindsay (2005) is added to the conversation for creating a more holistic image of an employable graduate. The concept of employability takes into consideration different perspectives and factors affecting one´s employability. Now as argued before university aims to give its´ graduates as good chances to make themselves employable as possible through education. In table 3 the concept of employability is presented.

This concept takes into consideration not only the individual but also the other factors that affect gaining a job in the current job market at any given time. McQuaid & Lindsay (2005) have divided employability into three different aspects that consists individual factors, personal circumstances and external factors.

Table 3 Employability factors (McQuaid & Lindsay, 2005)

INDIVIDUAL FACTORS	PERSONAL CIRCUMSTANCES	EXTERNAL FACTORS
Employability skills and attributes Essential attributes Personal competencies Basic transferable skills Key transferable skills High level transferable skills Qualifications Work knowledge base Labour market attachment	**Household circumstances** Direct caring responsibilities Other family and caring responsibilities Other household circumstances	**Demand factors** Labour market factors Macroeconomic factors Vacancy characteristics Recruitment factors
Demographic characteristics	**Access to resources** Access to transport Access to financial capital Access to social capital	**Enabling support factors** Employability policy factors Other enabling policy factors
Health and well-being Health Disability	**Work culture**	
Job seeking		
Adaptability and mobility		

From the factors listed by McQuaid & Lindsey (2005) employability skills and attributes are in the interest of this research and they are presented in more detail in table 3. Employability skills and attributes are often considered to be the most influential part of individual´s probability on getting a certain vacancy (McQuaid & Lindsey, 2005). Work knowledge base and labour market attachment will be discarded as universities do not directly try to contribute to those through individual´s education. Qualification is thought as formal education through higher education and thus is an assumption in context of this thesis and will be only mentioned.

Table 4 Employability factors and attributes in detail (McQuaid & Lindsay, 2005)

EMPLOYABILITY SKILLS AND ATTRIBUTES		
Essential attributes Basic social skills Honesty and integrity Basic personal presentations Reliability Willingness to work Understanding of actions and consequences Positive attitude to work Responsibility Self-discipline	**Personal Competencies** Proactivity Diligence Self-motivation Judgement Initiative Assertiveness Confidence Act autonomously	**Basic transferable skills** Pose and document literacy Writing Numeracy Verbal presentation
Key transferable skills Reasoning Problem-solving Adaptability Work-process management Team work Personal task and time management Functional mobility Basic ICT skills Basic interpersonal and communication skills Emotional and aesthetic customer service skills	**High level transferable skills** Team work Business thinking Commercial awareness Continuous learning Vision Job-specific skills Enterprise skills	**Qualifications** Formal academic and vocational qualifications Job-specific qualifications
Work knowledge base Work experience General work skills and personal aptitudes Commonly valued transferable skills (e.g. driving) Occupational specific skills	**Labour market attachment** Current unemployability/ employability durations Number and length of spells of unemployability/inactivity Balance of work history	

Adding these skills into the whole picture of professional skills that make an employable graduate from a non-domain specific perspective and the result may be seen in figure 3. Not all the skills are included to keep the image manageable but the excluded skills may be found in table 4.

Figure 3 Professional skills simplified.

3.2 Product design expertise

What is an excellent product designer like? What is considered as good design? Both questions are important when educating new product designers. However neither question is simply or unequivocally answered as there may be many correct answers. This section explores what is considered as good design and thus might characterize its creator and what skills she/he might possess. Some of the most notable academics who have investigated design activity and professional designers include Nigel Cross, Bryan Lawson, Donald Schön and Kees Dorst whose work also offer the backbone of this review.

The intentional product-focused design has its base in engineering (Leifer & Steinert, 2011). However, now in the times of rapid changes the intentional and successful is more complex than ever before design. It is not enough to design incremental development based on technological improvements, successful products have to take into account larger entities. This means a design that applies the context, the social aspects, the complexity, while understanding that a new successful design enables its users to be able to change their behaviour willingly. That is what a successful product at least excels to do. (Leifer & Steinert, 2011)

There is an interchangeable and overlapping use of product design and product development in the literature (c.f. Lindbeck & Wygant, 1995, Ulrich & Eppinger, 2012, Otto & Wood, 2001). Both terms are used for describing the activities and the people conducting the activities that produce

products for markets. Furthermore the word design itself is problematic in the Finnish language as the translation has double meaning depending on the context. The English word design may be translated to industrial design or to design in more general sense as in engineering design and architectural design and the furthermore it may symbolize both the activity and the end results. In this thesis the word design used and it is considered as a broad concept of deliberate and professional planning and design process of making a product.

> *"Everyone designs who devises courses of action aimed at changing existing situations into preferred ones"* Simon, H. (1969, p.111)

Design as an activity is not an easy one to define (Lawson & Dorst, 2009) as it can be used in many different contexts. According to Lawson and Dorst (2009) it is something that every human being does on different forms. Anybody given a task to design something to solve a problem can come up with a solution by utilizing mere common sense. Nonetheless the difference of the design profession and common human activity of designing brings up the differences in between the quality and how to attain the high level design. The design professionals are expected to be able to design on high level without that much context-dependency as any human being designing with common sense.

> *"Design is the conscious, human process of planning physical things that display a new form in response to some predetermined need*" (Lindbeck et al., 1995)
>
> *"A reflective conversation with the materials of a situation a kid of process"* (Schön, 1983, p.172)
>
> *"[design] a specification of an object, manifested by an agent, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to constraints"* (Ralph & Wand, 2009)

Considering design as an activity of problem solving there are several ways of presenting the design process is that may be found in figures 4 and 5. The different design processes also resonates with the different ways of defining design. Figure 4 is the representation of a design process brought forth by Lawson and Dorst (2009). Figure 5 is often used in engineering context (Ulrich & Eppinger, 2012).

However Lawson and Dorst (2009) want to make it clear that design is not only about problem solving and design cannot be only defined as problem solving activities. Design problems are often described as wicked problems (Buchanan, 1992). The defining elements of wicked problems are that there is not only one way of formulating the problems but rather a multiple possibilities of problems formulations that may lead multiple solution spaces. Wicked problems do not have right or wrong answer but good or bad solutions and each problem is unique. (Buchanan, 1992) Schön (1987, p.157) describes design challenge as "uncertain, unique and conflicting" by nature. It could be said that design aims for clearance and resolution of conflicts in a unique setting.

Figure 4 A design process adapted from Lawson & Dorst (2009).

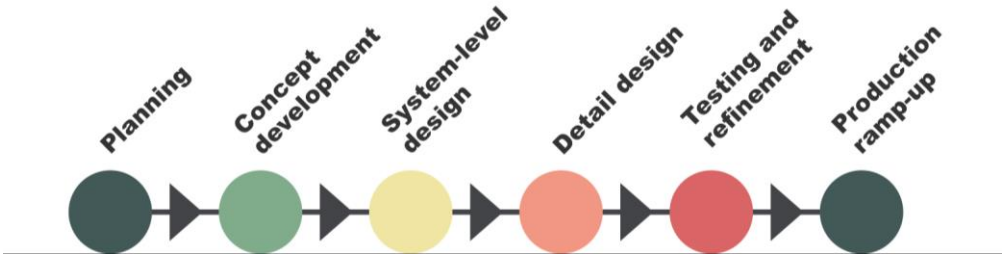

Figure 5 A product design process adapted from Ulrich & Eppinger (2012)

When designing a product one without a doubt aims for designing a successful and valuable product for its user. Defining and describing a good design is purposeful for teaching future designers and product developers. What then can be considered as successful and good design? Understanding at least some aspects of good design may ease the creation of what of characterizes its creator and what is expected of an expert designer. The description of successful design is presented in a lightly manner as it is not the main focus of this thesis.

Design can be attached to different contexts and that makes it harder to find a consistent track of literature that would define as good design. In this thesis it is though as a broad concept and thus the literature is brought from different contexts of design. According to Lawson and Dorst (2009, p.30) "*good design […] one that solves the problems at hand while creating value for the client and prospective user*". Norman presents in his book ´Living with Complexity´ (Norman, 2010a, p.10) that bad design that is complex creates confusion and frustrations just as well good design that is inevitably complex may be able to give its user "*desirable, pleasurable sense of empowerment*". According to Norman (2010a, p.14) the world is complex and the things designed today may be complex accordingly as too simple thing may be translated to be unenjoyable as they are dull. According to Brown (2009) a framework covering three specific words is one way to describe good design, especially in the design thinking (further explained in

chapter 3.2.2). The framework is presented in Figure 6. The words are representing different aspects of product design. Feasibility attends to what can actually be done, what is possible in engineering, viability reflects business aspect of product design – what would be viable and desirability refers to users and human-centred design. (Brown, 2009)

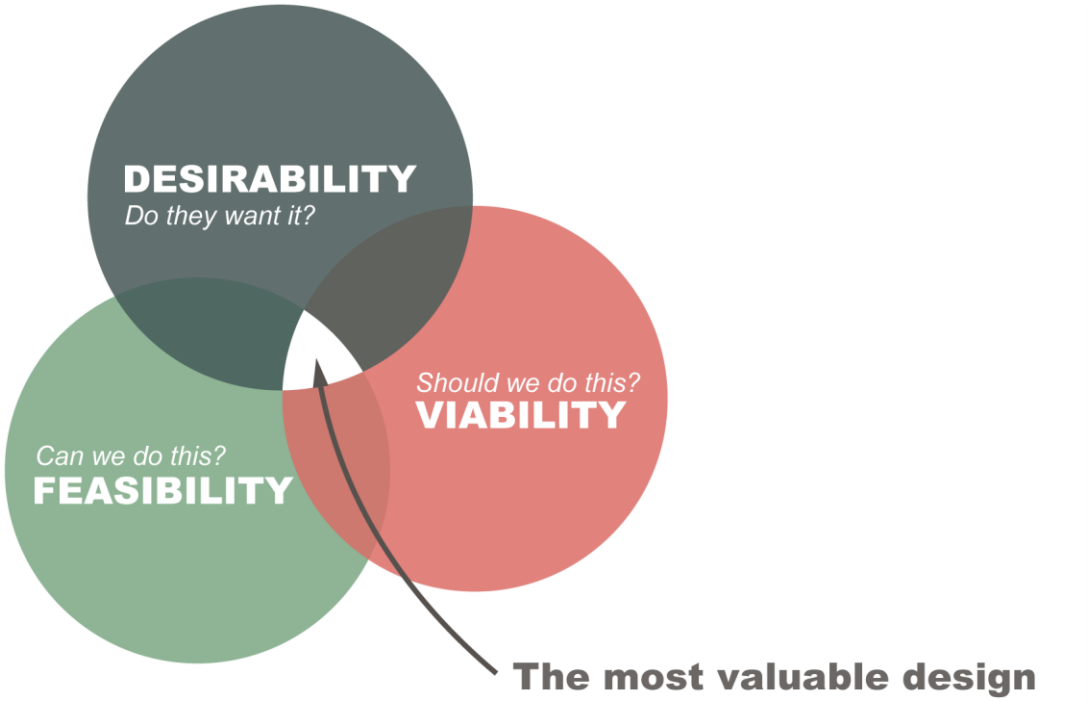

Figure 6 Valuable design according to Brown (2009)

In this thesis the interest is focused on getting familiar what the expert designers do, know and what skills they possess. All experts are created not born (Lawson & Dorst, 2009, p. 82) and as in any field of study students need to learn first before being entirely able to incorporate the idea of designing into action. However it is not only about learning about what is done in design but also how is to be a designer and growing into being one (Adams et al., 2011)

3.2.1 Characteristics of an expert designer

Being and acting as an expert in the field of design is still not fully understood regarding the skills and behaviour (Cross, 2004, Cross, 2011, Lawson & Dorst, 2009). Research has been able to suggest some characteristics and skills that seem to be shared by expert designers across different domains (Cross, 2004, Cross, 2011, Lawson & Dorst, 2009, Eckert et al., 2010). These characteristics and actions will be investigated and presented in this section acknowledging that at the same time there is still not a clear picture of design expertise developed in the literature.

Expert designers across different domains acknowledge and understand each other as designers (Eckert et al., 2010) and seem to possess some similarities regardless the speciality (Cross, 2004, Lawson & Dorst, 2009, Eckert et al., 2010). Regardless that there seem to be similarities in some aspects, there are also differences that are domain-specific (Cross, 2004). The definition of design may change according to certain domain and the perspective, the

processes and the ways an expert designer works and behaves during a design process may differ to some extent accordingly (Eckert et al., 2010).

As there is no unequivocal opinion available of design expertise, the characteristics presented here are for the most part at general level and describe the cross-domain characteristics and actions that have been identified in the literature. Furthermore some differences in behaviour and processes in between the novice and expert designers are presented in literature (c.f. Cross, 2004, Björklund, 2013, Adams et al., 2003) These differences will be presented in this section also alongside with the characterizations of an expert designer.

Across the reviewed literature the characteristics that research has been discovering are here labelled as: design cognition, experience, mindset and communication – they are further explored below. The categorizations is not putting these characteristics or skills in order rather than simply giving names to the suggestions that research suggests of expert designers. The categories are not mutually exclusive but may overlap.

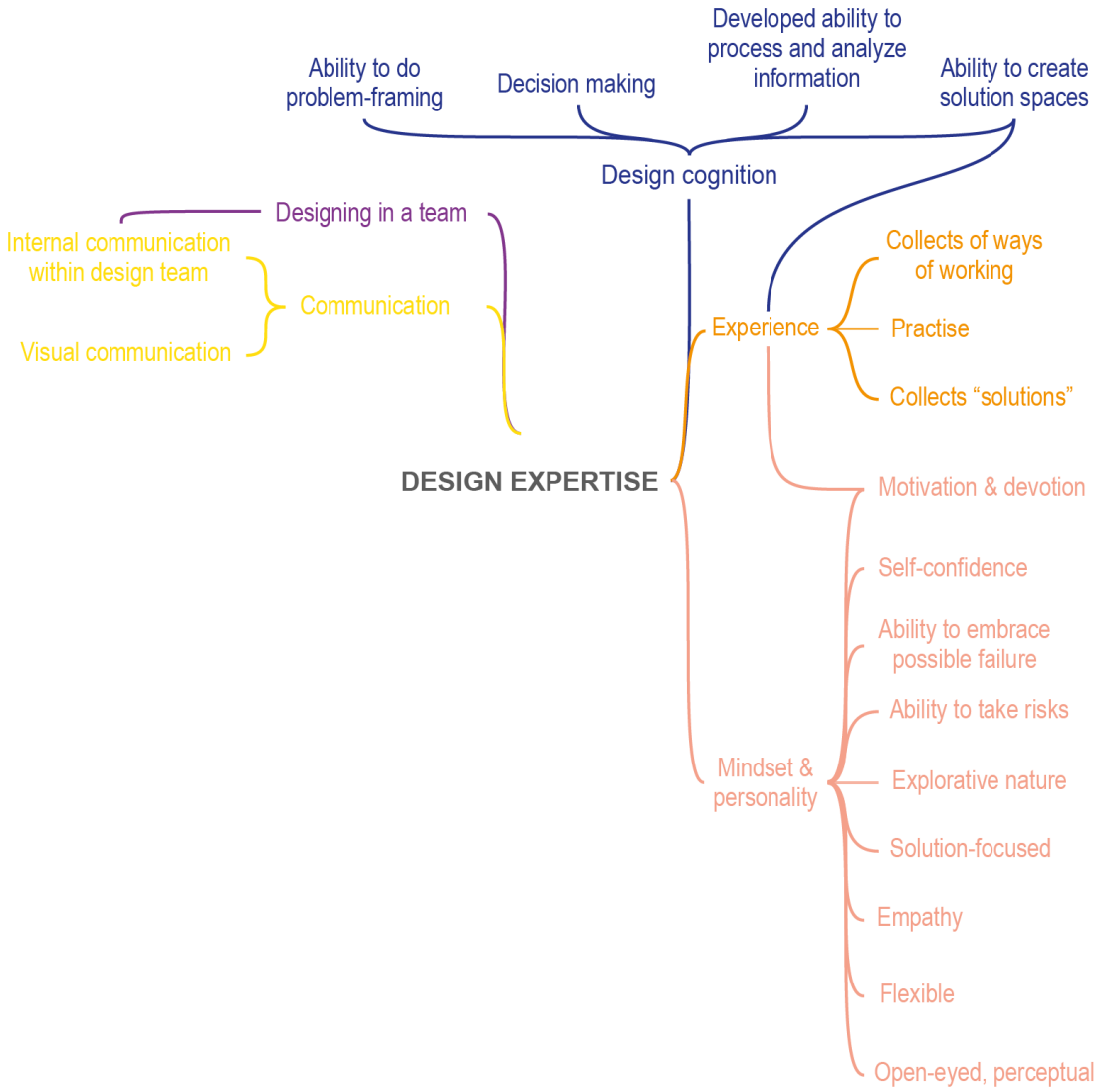

Figure 7 Compilation of design expertise

Design cognition

In many sources the cognitive processes practices and capabilities have been argued to be one of the key elements of product designer (c.f. Cross, 2011, Lawson & Dorst, 2009). Product designing, according to these researches, is more than anything a cognitive action and a process that is trained for finding possibilities and solutions for design challenges (Cross, 2011, Lawson & Dorst, 2009). According to Lawson and Dorst (2009, p.109) thinking is the foremost important skill for a designer.

Lawson and Dorst are not alone with their opinion as Schön (1983, p.268) describes the cognitive process used by design practitioner he calls ´reflection-in-action´ as follows: "The inquirer remains open to the discovery of phenomena incongruent with the initial problem setting, on the basis of which he reframes the problem." This would mean that when starting a design process the designer stays open to new issues that challenges the frame used at that moment for creating a new frame in which one may continue the process. This situation´s back-talk as Schön calls it through reflections turns into the frames and through those frames into new solution spaces within a frame. (Schön, 1983) In the process of creating the solutions designer uses pieces of her/his former knowledge as a metaphor and a new solution. Cross (2011) has similar view on design as Schön.

Cross (2011) argues that most of design happens in an intuitive way, even in engineering design. Cross suggests that there ought to be a concept of design intelligence. Design intelligence in his words involve seamless operation in between different levels of details, problem framing, of gathering and structuring data, an intense and reflective interaction with representations of problems and solutions and an ability to shift easily and rapidly between concrete representations and abstract thoughts – between doing and thinking. Now the difficulty seems to lay in the fast changes from problem framing into problem solving and thus spending too much time on information gathering instead of actually designing and learning that way. These actions seem to be highly developed cognitive functions and as many functions may be trained and thus developed by any individual.

Lawson and Dorst (2009) taking their base on suggestions by Nigel Cross and present the same process in slightly different words. ´Moving´ as in making design propositions as in making moves when designing, ´representing´ when these ideas are then represented in some visual manner, ´formulating´ as in the skills necessary for higher level of problem understanding and describing ending in the ´evaluating´ that is the set of skills that are guiding the ´moving´ taking into consideration the requirements present. The last set of skills they call ´managing´ that aim to keep the design process on the track and focused. (Lawson & Dorst, 2009)

One distinctive cognitive action identified is problem framing and the way an expert designer approaches design challenge (Björklund, 2013, Eckert et al., 2010, Cross, 2004, Lawson & Dorst, 2009, Schön, 1983). Problem framing seems to be related to all different forms of applications of design no matter the domain and it seems to be carried throughout the whole design process (Cross, 2004, Cross, 20111, Eckert et al., 2010). It is widely suggested that expert designers frame the design challenge in a more challenging and generative way and ask for more information along the design process (c.f. Cross, 2004, Cross, 2011 Björklund, 2013, Eckert et al., 2010, Lawson & Dorst, 2009). The expert designer seems to have higher ability for constructing a mental representation of design problems (Björklund, 2013). Cross (2004) describes this problem framing to be one of the differences in between expert and novice designer. The expert designers seem to approach the problem, reason their way through it and while discovering different solutions spaces, they seem to be able to keep on coevolving the

problem framing alongside with the development of solutions spaces (Cross, 2004, Schön, 1983). Novices attend on design challenges depth first and the experts go wide first (Cross, 2011). Expert designers use early design conjectures and use those as a way to explore a design problem (Cross, 2011). The experts seem to use generative or abductive (Dorst, 2011) thinking instead of deductive which seems to be the contrary for the novice designers who seem to use deductive thinking (Cross, 2004). According to Adams et al., (2003) even having only slightly more experience translates into an ability to make more moves in between the activities such as problem setting and problem solving. The creation on multiple options of different concepts for design solution is often brought as an important factor but Cross (2004) suggests that that might not be the best scenario. It might be more valuable to concentrate on the cognitive activities and switching in between the different types of mindsets of problem framing and solutions (Cross, 2004) instead of focusing on the number of solutions created.

The ability of going through the cycles of problem framing and solution spaces is not the only cognitive action defining designers. Expert designers seem to be capable of handling large amounts of data regarding the problem at hand (Lawson & Dorst, 2009). Lawson and Dorst (2009) in their book present with different examples that when growing into a more developed professional the way people seem to handle information changes. Instead of just gathering up pieces of information the experts are suggested to store information in larger ´chunks´ in their brain and they seem to be able to integrate new information more effectively with old information. They give an example of playing chess where excelling players seem to recognize the situation on the chess board instead of assessing it. Similar example from mathematics and physics as a school subject are the most difficult part of learning them is to tell apart different types of mathematical and physical problems, instead of actually using the formulae (Lawson & Dorst, 2009). This similar usage of gathered information and base knowledge of existing solutions seems to function in design accordingly. Even though the difference being that the problem setting is very different from design problems, the latter being ill-defined and often open-ended and the first well-defined. Cross (2011, p.74) suggests that the idea of using the data and experiences from the past is not about finding patterns in the problem framing rather than *“creating a pattern that re-formulates the problem and suggests directions towards a solution.”*

Adams et al. (2003) conducted a study in which engineering students got a design challenge and the observed results give insight about what were the differences in between juniors and seniors. Seniors were able to gather more data and pieces of information than freshmen. Same tendency was observed when the study investigated the iterations done during design process. Senior students also were able to consider more issues related to the challenge at hand. According to Kleinsmann et al. (2012) there are differences in between design experts and novices regarding the ability to evaluate the information according to its relevance and quality in respect to a design problem. Novices were less capable of doing distinction in between relevant and irrelevant information.

Among the already introduced cognitive actions another skill possessed by an expert designer, according to Lawson and Dorst (2009), is sophisticated decision making that combines the multiple design alternatives into one design solution while considering the specific limitations. These ways of making a continuous judgements and decisions are important learning in the way of becoming an expert designer (Lawson & Dorst, 2009). Expert designers do not get carried away with their fresh ideas but instead evaluate them prior to implementation (Cross, 2011). They seem to be able to assess the benefits and possible short-comings of a concept, acting like this they save time during the design process (Lawson & Dorst, 2009). Succeeding as a

designer is not only about original designs, critical skills include just as well as understanding the technical requirements of certain object and how that specific object can be made and what kind of performance is expected by the object in question (Lawson & Dorst, 2009).

Experience

Experience can be seen in many different professions and most definitely is true in design, without practice no one becomes a professional (Lawson and Dorst, 2009). Becoming a design professional according to Lawson and Dorst (2009) is not only about learning design skills but also gathering design experiences from different projects and having time and devotion (Cross, 2011 p.146). Designers seem to gather more influences from ways of doing things and solutions instead of theories. Just as well being exposed to different designs contributes into the designers experiences and later might translate into design solutions (Lawson & Dorst, 2009) For novices finding and looking for inspiration from outside and others´ designs could lead to an extensive gathering of concepts that with the more boundary breaking objects and concepts hopefully enable the novice designer to reflect upon and thus giving space for new boundaries found in novices mind (Lawson & Dorst, 2009). These gathered concepts and experiences Lawson and Dorst (2009) call design precedents and they argue that more experienced designers use the precedents in their process of design. They also present the idea that most of the novice designers are taken on many field trips to see different designs, art and to gather inspiration, just as well they are encouraged to carry a sketchbook to record the ideas at all times. Discussions and debates during evaluations may increase the awareness and hence go alongside with the ability to reflect and create solutions.

For gathering the ever so important experiences also time and devotion are needed (Cross, 2011). In any field study practice makes all the difference and having the motivation to go through that practice. Cross (2011) suggests that novices need a lot of training that ought to be done under a guidance of a skilful teacher. Not practicing design but being exposed to different ways of solving problems in ones chosen domain thus gathering the base data that enable faster production of solutions (Cross, 2011). This ought to happen in order make sure that future designers gather related and significant experiences that may one day translate into solutions spaces (c.f. Laakso & Liikanen, 2012, Petre, 2004).

As presented above design cognition consists of the ability to create generative problem framing, solution spaces, gather enough data and reflect the situation at hand with the experiences one has had before. When combining these and all the experiences, solutions seen before and knowledge learned before become necessary and transform into solution spaces.

Mindset and personality

Not everybody makes a good professional designer. There are some characteristics in regards to personality that Cross (2011) suggests being fairly similar for all those design experts that he has studied. Strong personal motivation and interest, high drive, self-confidence, the attitude of taking risks and being prepared for the possibility of great failure were the named characteristics. Lawson and Dorst (2009) suggest that empathy is something that a successful designer will need in order to understand users and clients and relate to their situations. Some further personal characteristic of designers have been described by Lawson and Dorst (2009, p.188) as well: designers seem to be more flexible, spontaneous in their approach, open-ended

and perceptual by nature. Cross (2011) presents some characteristic of the outstanding designers discovered through case studies: ability to survive the ambiguity, the attitude of taking risks and being prepared for the possibility of great failure, the ways of working may not be systematic during the design process itself and acting in a proactive manner. Lawson and Dorst (2009) believe that being creative and having an ability to create value and innovative designs is about keeping your eyes open and alert to the possibilities that might not be clearly seen.

Explorative nature of an expert designer has been suggested to translate into an activity. All designers seem to have a desire for experimenting with materials in order to produce a design (Eckert et al., 2010). They also seem to have an inclination to explore new ideas and possibilities through for example sketching, through modelling and by exploring. Schön (1983) suggests that engineering design as a process seems to be acting based on the primary knowledge of the situation and the actions taken are experiments that bring up new questions and necessities for new experiments according to the laws of physics or chemistry and thus creating new frameworks. The process may be seen as very similar to the one that he has found out that architects do, only the media is different: sketching and models. Reflection comes out when experiment give new pieces of information in one form or another. (Schön, 1983)

Communication skills and forms

Communication rose as one of the themes that the researchers highlighted as a central and necessary skill for a designer. In this case they referred to both internal communication for example within a design team as well as the communication with stakeholders. Lawson and Dorst (2009) argue that a designer is visual thinking and translating thinking into visual communication is an important skill. A visual manner of communicating for example using mind maps (Kokotovich, 2008) may ease the process of designing and understanding the complexity of a design challenge for novice designers. Visual communication is a way for a designer to communicate with her/himself for example through sketching (Eckert et al., 2010, Schön, 1983) when creating solutions or as tool to communicate with others (McDonnell, 2012).

Verbal communication means that designer uses meaningful words that are appropriate for a specific domain when describing a design and talking about it (Lawson & Dorst, 2009). An important factor for verbal communication is the way designer represented their ideas clearly as appropriate way of representing was critical for interaction within team and outsiders (Eckert et al., 2010). It is suggested (McDonnell, 2012) that in design context that during a design session the tentative verbal communication in between the two designers involved was accommodating the disagreements. The language the designers were using was tentative and enabled the other designer´s opinion while not discarding one´s own opinion. According to McDonnell (2012) this kind of verbal communication seems to facilitate smooth collaboration. Also they discovered that in this study the two designers did not try to persuade their own views on how to solve the design challenge but were able to incorporate both vies into the proposition.

Related to communication and knowledge sharing according to a study (Kleinsmann, 2012) expert designers are able to productively share needed pieces of information with their team members. The novice designers share knowledge that might not be as relevant as the information experts share. The language and metaphors that experts use are enabling effective frameworks and thus using their former experiences for the creation of solution spaces as they are “modelling the unfamiliar on to the familiar” (Schön, 1983, p.186). Schön calls that “seeing-as”.

Designing in a team

Cross (2011) handles team working in the context of product design and points out that there are some clear differences in between working as a single designer and as a design team. The communication is more crucial for the design process as well as planning not only the necessary practices but also the let the unplanned instances that enable new exploratory events to happen. The unplanned exploratory activities are more present in the concept development phase. Cross (2011) suggests that the opportunistic behaviour observed with single designers may be difficult to facilitate in a team work context. Cross (2011) proposes that equally important is that a design team has a common goal and that the problem solving should go just as when there is only one designer – the re-formulation and parallel development of the problem and problem setting are just as important. A design team also has roles for its members, formal or informal, and the roles may vary depending on the activity and organization. Cross (2011) points out the advantage of working in a team that can be shown in a larger number of concepts ideated. The challenges lying in the team work itself as possible conflicts and differentiating understandings that when unsolved may hinder any design project. In the concept generating phase Cross (2011) describes it being normal that as designers often come even emotionally attached to a certain concept that in a team different members may favour different concept and may try to convince other team members on their side. A professional design team knows how to act collaboratively (Kleinsmann et al., 2012). The team members know their position in the team, their role regarding their own specific field and are able to share the necessary and relevant information regarding their domain and roles with the team (Kleinsmann et al., 2012). Knowing what is relevant information, trusting others and using tentative communication one leaves room for other team members to share their ideas creates a collaborative way of working. It is suggested that novices exhaust team members with endless amount of possibly irrelevant information (Kleinsmann et al., 2012). A professional team is able to address the complexity, aimed for founding design principles for the design challenge thus getting the discussion going on about level of goal instead of details (Kleinsmann et al., 2012).

3.2.2 Design Thinking

Design thinking is a very fashionable concept nowadays gathering attention and hype (Kimbell, 2011, Hassi & Laakso, 2011, Dorst, 2011). It is thought to solve different kinds of problems in different fields from management to innovation as well as it is generally thought to be very recent discovery brought to the lime light by the design consultant company IDEO (c.f. Design Council UK, 2011). However the concept design thinking has been along for a longer time than that, the first mentions of it in the literature are already from the 1960´s (Cross, 2011, Hassi & Laakso, 2011).

As the term design thinking and its usage vary depending on the sources, an all covering description is not available and thus design thinking remains debatable by its definition (Hassi & Laakso, 2011, Rogers, 2013). Hassi and Laakso (2011) identified two discourses regarding design thinking – design discourse and managerial discourse. Hassi and Laakso (2011) identified the design discourse of design thinking reflecting on Schön´s work “Reflective practitioner” (1983) as well as Simon´s work “The sciences of the artificial” (1969). Managerial discourse has surfaced later along with IDEO (Hassi & Laakso, 2011). There are different definitions for design thinking presented below:

"A methodology to generate innovative ideas" (Rogers, 2013)

"An analytic and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign."(Razzouk & Shute, 2012)

"A methodology that imbues the full spectrum of innovation activities with a human-centered design ethos." (Brown, 2009)

"A public relation term for good, old-fashioned creative thinking" (Norman, 2010)

Regardless of the difficulties on defining design thinking unequivocally, it is still considered as important part of a the design skills on the 21st century (Razzouk & Shute, 2012) and a framework proposed by Hassi and Laakso (2011) resonate with the design skills and characteristics presented above in chapter 3.2.1 Characteristics of an expert designer. In table 5 the frameworks is presented and it has been gathered through relevant literature of design thinking. The framework is divided in to three parts: "practices, cognitive approaches and mindset".

Hassi and Laakso (2011) present a question whether there are differences in between the two discourses. Now, without taking part in the conversation of design thinking and the difficulties of defining design thinking, it could be suggested that design thinking could be considered as part of characteristics of an expert designer (Laakso & Clavert, 2014) – explicitly or implicitly based on the similarities between design thinking and the skills named in the earlier chapter. One way of seeing design thinking is as a batch of skills that are seem to be appropriate for solving design challenges. Some of these skills may be shared with professional skills though important today and in the future, such as interdiscilpinary collabiration, teamwork.(Laakso & Clavert, 2014) The framework resonates strongly with the skills and characteristic presented above that it in this context it is difficult to differentiate design thinking from the skills. However due to the lack of consistent definition it may be best not to use design thinking as a single concept for describing characteristics and skills of an expert designer. Rather it might be valuable to keep design thinking as part of design expertise and possibly using the ´IDEO´ approach on design thinking as a way of giving user-centeredness more attention.

Table 5 Design thinking framework by Hassi & Laakso (2011)

PRACTICES	THINKING STYLES	MENTALITY
Human-centered approach E.g. People-based, user-centered, empathizing,ethnography,observation (e.g. Brown 2008; Holloway 2009; Ward et al. 2009)	**Abductive reasoning** E.g. The logic of "what could be", finding new opportunities, urge to create something new, challenge the norm (e.g. Fraser 2009; Lockwood 2009; Martin 2009)	**Experimental & explorative** E.g. The license to explore possibilities, risking failure, failing fast (e.g. Brown 2008; Fraser 2007; Holloway 2009)
Thinking by doing E.g. Early and fast prototyping, fast learning, rapid iterative development cycles (e.g. Boland & Collopy 2004; Lockwood 2010; Rylander 2009)	**Reflective reframing** E.g. Rephrasing the problem, going beyond what is obvious to see what lies behind the problem, challenge the given problem (e.g. Boland & Collopy 2004; Drews 2009; Zaccai in Lockwood 2010)	**Ambiguity tolerant** E.g. Allowing for ambiguity, tolerance for ambiguity, comfortable with ambiguity, liquid and open process (e.g. Boland & Collopy 2004; Cooper et al. 2009; Dew 2007)
Visualizing E.g. Visual approach, visualizing intangibles, visual thinking (e.g. Carr et al. 2010; Drews 2009; Ward et al. 2009)	**Holistic view** E.g. Systems thinking, 360 degree view on the issue (e.g. Dunne & Martin 2006; Fraser 2009; Sato 2009)	**Optimistic** E.g. Viewing constraints as positive, optimistic attitude, enjoying problem solving (e.g. Brown 2008; Fraser 2007; Gloppen 2009)
Combination of divergent and convergent approaches E.g. Ideation, pattern finding, creating multiple alternatives (e.g. Boland & Collopy 2004; Drews 2009; Sato et al. 2010)	**Integrative thinking** E.g. Harmonious balance, creative resolution of tension, finding balance between validity and reliability (e.g. Brown 2008; Fraser 2009; Martin 2010)	**Future-oriented** E.g. Orientation towards the future, vision vs. status quo, intuition as a driving force (e.g. Drews 2009; Junginger 2007; Martin 2009)
Collaborative work style E.g. Multidisciplinary collaboration, involving many stakeholders, interdisciplinary teams (e.g. Dunne & Martin 2006; Gloppen 2009; Sato et al. 2010)		

3.3 A professional expert designer

In the characterization of a professional expert designer general professional skills and design expertise were explored. The visualization of the findings is seen in figure 8. A professional expert designer has both professional skills and design expertise. Professional skills were mapped from different sources and design expertise was explored through the literature.

A professional has good communication skill, works well in a team setting and has personal competencies such as motivation, diligence, self-management and works in a proactive manner (c.f. McQuaid & Lindsey, 2005, Shuman et al., 2005). Having the proper skills affect on graduates´ employability and hence it is important that universities pay attention providing their graduates with proper skill set (MCQuiad & Lindsey, 2005).

Design expertise according to some of the notable researchers includes design cognition, experience, communication, mindset and the designerly personality and knowing how to be part of design team (c.f. Schön 1983, Cross 2011, Lawson & Dorst, 2009). In design cognition there were four subthemes: problem-framing, decision-making, advanced ability to process information and ability to create solution spaces. Experience means willingness of

collecting ways of working, solutions and ideas of surrounding world and practicing. Mindset and personality described common characteristics of expert designer – they were driven, motivated, solution-oriented, flexible, empathetic and understand the necessity of ´failing´. Their desire to work in an experimental way, using for example experiment, sketching and modelling for inquiring new information and creating solutions. Expert designers had communication skills for visual communication as well as collaborative way of communicating with a team. They want to find proper words for describing design problems and framing them (Schön, 1983). Working in a design team means having a shared goal, trying to facilitate the unplanned exploratory activities that single designer may do easily (Cross, 2011). In a team setting an expert designer knows her/his place and role, knows what his/hers own domain expertise may contribute to the designing situation and shares the appropriate information with team (Kleinsmann et al., 2012).

Design thinking deserves to be mentioned in this context of design expertise as it has gotten a lot of attention in the resent years (Kimbell, 2011, Hassi & Laakso, 2011) At the moment there a variety of definitions for design thinking but it this thesis it can be observed through the framework provided by Hassi & Laakso (2011) found in table 5 in page 29. It resonates with the skills presented above and even though it is not counted here as a skill nor does it cover the skills presented above. It still is considered as a design skill (Razzouk & Shute, 2012) and would be worth communicating as one part of design.

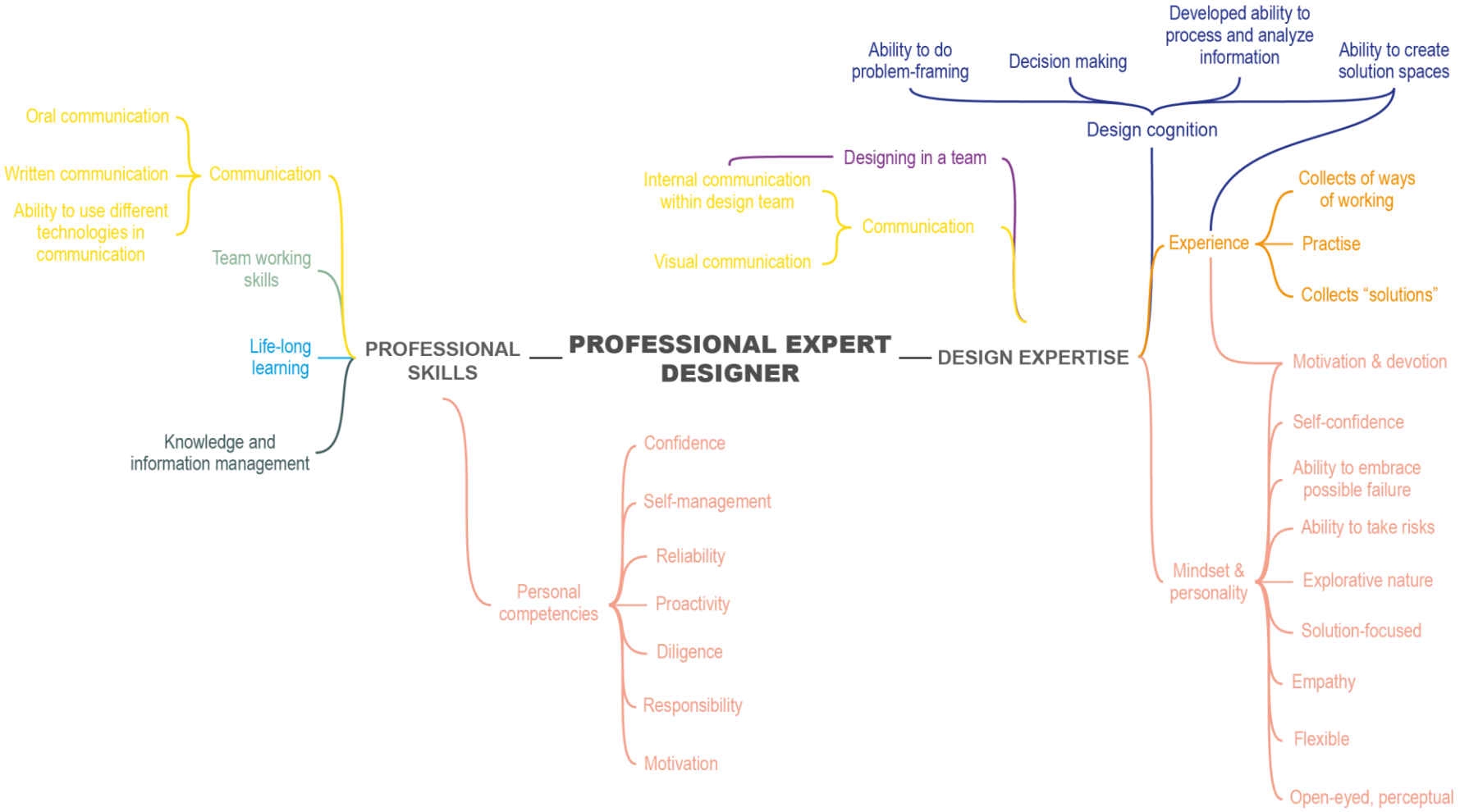

Figure 8 A visualization of skills and characteristics of a professional expert designer

4 Learning and teaching for the context of product development

In the previous chapter it was mapped what skills and characteristics an expert designer has according to notable researchers. This chapter aims to give a brief review about how one builds expertise through education, different ways of educating through literature review. The point of view taken here is that of engineering education as the focus is still held upon design context. This review is not intended as a thorough insight of pedagogical practices but rather a brief glance that presents ideas relevant in design education. The reason of this chapter existing in this thesis to broaden the perspective and the goal of presenting these ideas is to finally feed in to the discussion and reflection of the results of students´ interviews.

Higher education has been in motion and looking for changes in the recent year but are the changes fast enough. Learning has been slipping under the radar as higher education is getting more outcome-focused and this may not go along with implementing alternative learning strategies. Even though a shift has been going on to bring more educational perspective in engineering education (Froyd et al., 2012). Outcome-focused higher education places its attention in giving out knowledge and encouraging students only to execute the things they are told to do (c.f. Savin-Baden, 2000, 2007). However the idea of higher education should be to grow graduates as critical thinkers (Savin-Baden, 2000) as well as be preparing its students with appropriate skills and learning (Savin-Badden, 2007). The world today requires more than just graduates who are overloaded with domain-specific information. Graduates need to adapt quickly into solving multifaceted and complex challenges that may be from outside of their own expertise.(Laakso & Clavert, 2014)

4.1 Knowledge development and learning

Graduating from university is not a guarantee to be an expert in any field. That would be a mistaken view of academic studies.(Fry et al., 2003, p.19) The goal of higher education is to train and nurture higher thinking skills (Krathwol, 2002). The very nature of science is that on constructive learning however the learning process for students in universities seems to be often something different (Tynjälä, 1997). Teaching in university context should not be considered as only giving out information rather that learning should be thought as cognitive activity in which "*learner […] constructs knowledge by interpreting perceptions on the basis of prior knowledge and beliefs*" (Tynjälä, 1997, p.280). Bloom´s revised taxonomy is a representation of thinking skills and knowledge. It is a two dimensional model that combines different levels of knowledge and cognitive processes as seen in figure 9. The Bloom´s revised taxonomy may be seen as a route of growing into being a professional regarding knowledge and cognitive skills. Creating is seen as the highest form of cognitive processes and included in create there are different dimensions of knowledge. This model aims to give an idea how knowledge and cognition may be constructed. Considering that design activity defined by Lawson and Dorst (2009) is first and foremost a cognitive activity, it clearly seems to be aligned with Bloom´s revised taxonomy.

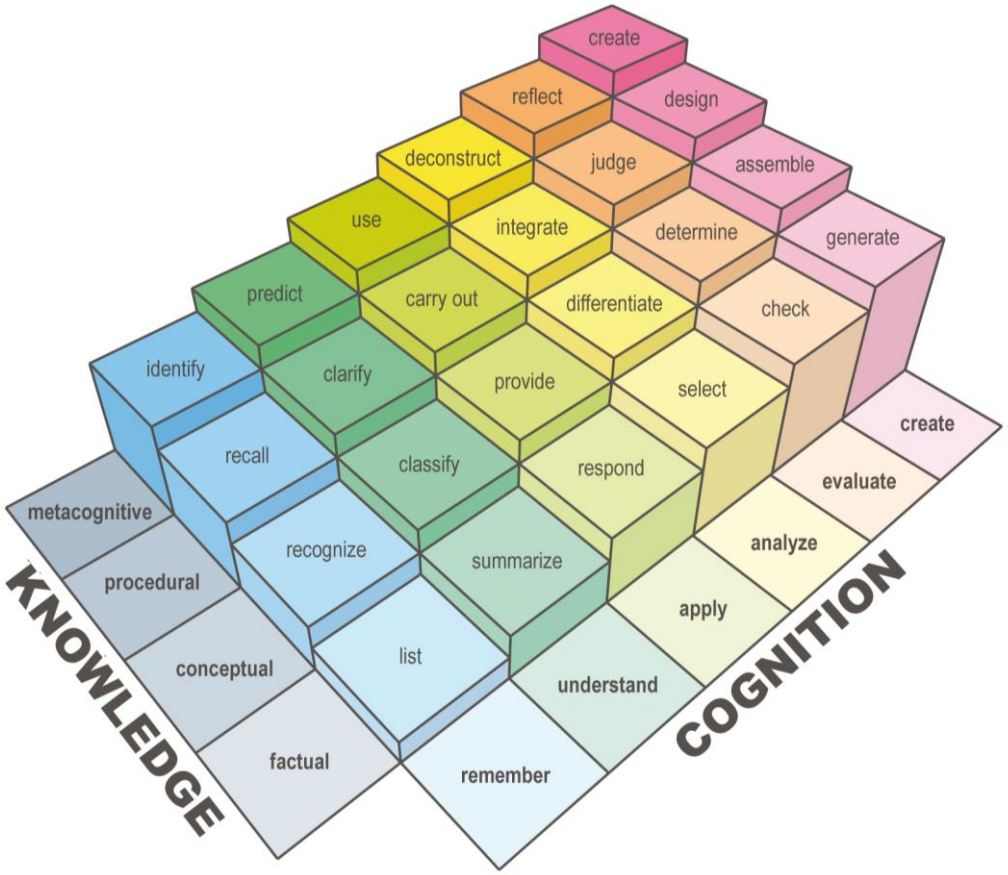

Figure 9 A model of learning objectives based on Bloom´s revised taxonomy visualized (Heer, 2009)

Growing from a novice into an expert requires hours of deliberate practice and understanding those larger concepts and principles. The difference in between novices and experts is both qualitative and quantitative. (Litzinger et al., 2011) Experts are able to make the underlying connections of principles with the matter they have at hand unlike novices who understand the situation superficially (Litzinger et al., 2011). This is aligned with Bloom´s taxonomy as shown that the dimensions of knowledge go from factual into metacognitive. Based on chapter 3.2 findings it may be argued that in the cognition process dimension designers ought to be able to practice the highest form of thinking as creating while also being able to use the other levels effectively as well. Now, considering that a depth of a design solution´s knowledge dimension may vary according to whether it is for example a new scientific theory or a machine. In order to get graduates as far along as possible in the process of covering all the dimensions of cognitive processes and knowledge education should be well planned, deliberate and well executed throughout the curriculum (Litzinger et al., 2011).

Lawson and Dorst (2009) have also argued that university is not an ideal place to become a thoroughly educated and competent designer. They suggest that the best outcomes would come through practice. University education in design at its best gives a strong base for becoming a competent expert designer. Doing practical work during studies is seen as necessary especially in the field of engineering which is an applied science (Fry et al., 2003) and thus needs clearly practical training. Furthermore it is difficult to see design itself being apart from practical work during studies. What would come out of doing for example engineering design only on paper? What learning experiences could enhance design expertise? Design

education plays a crucial role of being the facilitator for a student to grow up as a designer. This means just challenging the conventional ways of doing things (Lawson& Dorst, 2009). Schön (1987) shares the same view as he suggests that design as a practice is “learnable but not teachable” and he finds coaching and reflective practicum worth paying attention to.

Students are all individuals and they all learn in a different manner (Fry et al., 2003, p.20-22). There are different ways of classifying learners (c.f. Fry et al., 2003, p.20-22, Felder & Silverman, 1988) however at the same time it ought to be clear that in the higher education the students are more than ever before responsible for their own learning (Fry et al., 2003). Student´s own actions are more influential on the learning outcomes (Fry et al., 2003). Despite that students themselves are responsible for their own learning there seems to be a clear gap in between the teaching and learning styles in engineering (Felder & Silverman 1988). Felder and Silverman (Felder & Silverman 1988) argue that most of engineering students are visual, sensing, inductive and active and engineering teaching for the most part has been traditionally been auditory, abstract, deductive, passive and sequential. They have suggested that the opportunity is to change teaching style to better match the learning styles of engineering students. Some approaches that aim to solve these drawbacks are presented below.

When creating the instances for learning in higher education it should be taken into account that there are different point-of-views on adult learning. The acknowledgement of adult learning theories is drawing attention even though the adult learning theories are not undebatable. (Fry et al., 2003) Without going very deeply into the adult learning theories for, experiential learning theory, later referred to as ELT, by Kolb - revised version (2005) is briefly introduced as it resonates with Schön´s (1987) suggestions of learning design. Kolb (2005, p.194) bases ELT on six propositions:

> *1) Learning is best conceived as a process, not in terms of outcomes. To improve learning in higher education, the primary focus should be on engaging students in a process that best enhances their learning – a process that includes feedback on the effectiveness of their learning efforts.*
>
> *2) All learning is relearning. Learning is best facilitated by a process that draws out the students´ beliefs and ideas about a topic so that they can be examined, tested and integrated with new, more refined ideas.*
>
> *3) Learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world. Conflicts, differences, and disagreement are what drive the learning process. In the process of learning one is called upon to move back and forth between opposing modes of reflection and action and feeling and thinking.*
>
> *4) Learning is a holistic process of adaptation to the world. Not just the results of cognition, learning involves the integration functioning of the total person – thinking, feeling, perceiving, and behaving.*
>
> *5) Learning results from synergetic transactions between the person and the environment. In Pigaget´s terms, learning occurs through equilibration of the dialectic processes of assimilating new experiences into existing concepts and accommodating existing concepts to new experiences.*
>
> *6) Learning is the process of creating knowledge. ELT proposes a constructivist theory of learning whereby social knowledge is created and recreated in the personal knowledge of the learner. This stands in contrasts to the “transmission”*

> *model on which current educational practice is based, where pre-existing fixed ideas are transmitted to the learner.* (Kolb & Kolb, 2005)

The learning cycle that Kolb proposes is the following: concrete experience (CE) – reflective observation (RO) – abstract conceptualization (AC) – active experimentation (AE) and continuing back to concrete experience (CE) (Kolb & Kolb, 2005, Fry et al., 2003). The phases and the process may be seen as different ways of learning as well and the used mode may differ with situation (Kolb & Kolb, 2005). The proposal is that in order for the learning to effective one has to go through all the four phases (Fry et al., 2003). Individuals prefer different ways of learning (Kolb & Kolb, 2005) nonetheless is it possible to have for example both action and reflection at the same time (Fry et al., 2003). Schön (1984) suggests that it is exactly what professionals do when working calling it reflection-in-action. Learning to do reflection-in-action could then be one of the goals of growing into a professional designer.

Learning in design context

Design according to Schön (1987, p. 158-161) is learnable but not teachable but rather coachable as the designing as a process is 1) integration of reflection-in-action in which the designer is expected to do experiments through new pieces of discoveries of the earlier experiences, 2) a holistic skill in which the smallest of pieces must play their role in the bigger picture of a design and thus the decomposition of the design process may be hugely unfavourable, 3) an ability to understand and recognise characteristics and acting based on them, 4) skills of using descriptions and recognitions when designing, 5) design as a creative action aiming for something new. Schön (1987) proposes that in design education it is utterly important that students should be enabled to do the learning closely with actual doing while someone acts as a coach. A dialogue he describes in between a student and a coach entailing not only conversation but as demonstrations, performances, drawing the attention into the important features in both the design subject as well as the reflection-in-action and making thus explicit what may have been implicit.

Still it is important to note that a sole learning experience is not enough to make something as learned (Fry et al., 2003, p.136). The experiences should be reflected upon from the theoretical perspective. The importance in that light is to enhance the reflection students do as well as give support to boost especially the critical reflection. (Fry et al., 2003, p.136) This is a view that Lawson and Dorst (2009) share and they present some ideas about learning from projects in a design context. One critical way for designers is to learn from projects that they have been part of. However their main message is that learning might not take place regardless how many projects one takes part, not unless there are skills and values to enhance and maximize the learning. This means that there ought to be time and place for knowledge transference in between projects. Enabling reflection at the right time is the key because it is not valuable or needed all the time during a project. (Lawson & Dorst, 2009)

Importance and the usage of iterations during the design process are discussed by Adams et al. (2003) and the suggestion is that iterations may represent the reflection-in-action (Schön, 1983). They (Adams et al., 2003) see iterations as a way of assessing how well students learn effective design processes. Should iterations be more enhanced in the design process education? Van Dooren et al. (2014) share similar ideas and would like to enhance the importance of design process in design education. The goal is to make the students aware of the things they need to learn in order to create a design – the process is just as important as the final outcome design. Coaching the students to do the process in a less engineering way and trying to make the shift

into the more open-minded mindset should be taken into account (van Dooren et al., 2014). Engineering students are just as capable of convergent, divergent thinking styles and creative thinking as students of art (Williamson, 2011) maybe they are just not encouraged through education? Kleinsmann et al. (2012) suggests that in engineering education the students are often taught to be generalists and they might still lack the design collaboration skills. The study suggest that these skills regarding the information-sharing and –integrating could be taken into account more. (Kleinsmann et al., 2012)

4.2 Creating meaningful learning experiences

For creating meaningful learning experiences in design education one of the first things worth consideration may just be what is learning in the context of design and bearing in mind Schön´s proposal and Kolb´s theory of experiential learning. However not only the learning experiences but also simply giving opportunities for students to understand what are the qualities, knowledge and skills that they will need in the future. The studies ought to give possibilities to see through authentic activities that enable the integration of the knowledge gathered during studies (Litzinger et al., 2011). Litzinger et al. (2011, p.126) define effective learning experiences as follows:

> *"…those[experiences] that support the development of deep understanding, organized around key concepts and general principles the development of skills, both technical and professional and the application of knowledge and skills to problems that are representative of those faced by practicing engineers."*

In table 7 there are suggestions brought forth by Litzinger et al. (2011) with a goal to create those effective learning experiences. As presented in the table 7 arousing the interest of students to meet certain goals is one thing to consider. Thambyah (2011) presents a model that is based on Bloom´s revised taxonomy and creates a description of how these may be put as intended learning outcome levels. That description is presented in the table 6. The suggestion is that for creating mutual understanding and common language around Bloom´s revised taxonomy the wording in table 6 could be used for communicating the intended learning outcomes to students. It may help students to grasp the meaning of a course. Table 6 provides information for both a student and the course organizer giving meaning for different levels of knowledge and cognitive processes. On the other hand in table 7 there are more practical suggestions for a course organizer and planner in what to aim for with learning instances.

Table 6 Bloom´s revised taxonomy translated for intended learning outcomes (Thambyah, 2011)

	(1) Remember	(2) Understand	(3) Apply	(4) Analyse	(5) Evaluate	(6) Create
A. Factual	Able to show knowledge of the literature, the important authors, related terminology and key findings	Shows ability to classify, summarise and explain the basic information from the literature review.	Has the basic skills to carry out established procedures or experiments.	Verifies data are good. (e.g. checks for errors)	Interprets new data, together with relevant data that have been published before.	New knowledge is obtained from the findings using established methods of interpretation.
B. Conceptual	Shows knowledge of specific information on relevant theories, models, structures, principles, etc.	Able to infer the inter-topical relationships relevant to the project. 'Sees the big picture'.	Demonstrates the ability to put together different procedures or experiments in relation to the research question.	Able to differentiate data into relevant groups and major and minor components.	Able to articulate the validity or inappropriateness of the data in terms of addressing the research question.	Able to add a new level or dimension of interpretation to provide new knowledge.
C. Procedural	Describes clearly the previously used techniques, meth-ods, algorithms and/or equations relevant to the project.	Able to competently critique the previous methods and techniques used and identify gaps in current knowledge.	Shows ability to proficiently carry out the different experiments, giving considerations to safety issues and statistical significance.	Able to perform statistical analysis and organise data appropriately into spreadsheets, graphs.	Shows clear understanding of statistical significance, power and whether or not to accept or reject the hypothesis.	Provides a new 'revelation' or a meaningful interpretation through the use of clever writing or presentation techniques, e.g. analogies, illustrations, etc.
D. Metacognitive	Able to list the key issues from the literature review in order to help define the problem statement or research question.	Able to discern the critical issues and synthesise an exemplary problem statement or research question for the project.	Exhibits a high level of skill and good safety practice in carrying out complex experiments and producing high quality data.	Shows ability to reduce complex data into valid and easy-to-understand charts, diagrams or explanations.	Demonstrates an excellent ability to self-critique, able to list limitations of the data and experiment design and make new recommendations.	Able to show a keen sense of what knowledge is known vs. unknown, and why the nature of the knowledge is such.

Table 7 Creating effective learning experiences (Litzinger et al., 2011)

Affective
• Arouse interest for students of contrasting abilities and goals.
• Provide stimulating, interesting, and varied assignments that are within the range of students' abilities but challenge them to reach for the top of that range.
• Make connections to students' interests and intended careers.
Meta-cognitive
• Build self-regulative abilities by explicitly teaching students about them.
• Promote reflection to enhance attention to meta-cognitive aspects of learning.
• Provide timely and constructive feedback on the learning processes so students understand what they know and can do well, and what they need to improve.
Cognitive
• Engage students' prior knowledge through selection of learning tasks that are at appropriate levels of difficulty.
• Promote deep engagement with content through assignment design and tasks that require meaningful interaction with peers.
• Require students to integrate their knowledge and skills to complete increasingly complex assignments.
• Provide support to "scaffold" student learning, especially for assignments that require integration of knowledge and skills.
• Use assessments that make students' thinking processes apparent so their level of understanding can be assessed.
• Provide timely and constructive feedback that focuses on development of all elements required for expert-like performance: conceptual understanding, component skills, professional skills, and the integration of knowledge and skills.
• Use summative assessment techniques that evaluate and reward all elements required for development of expert-like performance.

4.2.1 Capstone courses

Froyd et al. (2012) present that there may be considered to either have been happening or is currently happening five major shifts in engineering education. One of those shifts presented by Froyd et al. (2012) is emphasis on engineering education. Engineering education has been attempting to put more effort by giving design opportunities for students and one way of implementing that effort is a capstone course. Product Development Project –course can be described as capstone course and thus providing the definition of capstone courses and their role in engineering education is in order. Capstone design courses have been created for a demand to involve more design experiences during the education. The word capstone however

is not necessarily often used in engineering education but it aims to describe a course that brings together content from different courses. (Froyd et al., 2012) In another words capstone can also been defined as “a senior-level design course in which students learn to apply their engineering and other skills to real-world engineering projects” (Todd et al., 1995). Capstone courses are seen as a good way to provide possibility to students to develop their skills, that way better readiness for work life and ease the transition (c.f. Davis et al, 2003, Hanse et al., 2007). Another perspective for students is to understand that as engineering in the real working life is not “a vacuum isolated” and that experience may be delivered through capstone courses (Hanse et al., 2007). In this thesis the assessment will not be looked into, however there are studies and some research done in the context of capstone courses (c.f. Trevisan, et al., 2006, Montfort et al., 2012, Davis et al., 2012).

4.2.2 Learning environment and social factors

The educational curriculi may be carefully planned and the course contents defined to the very last detail but learning seems to be in relation to other factors as well not only to the content taught. Some suggested factors are social or informal learning and the physical spaces for education in design context.

Flying solo has its place in learning context but at its best learning is social collaborative and cooperative cognitive action that its affected by social and comminitial atmosphere as well as the physical setting and space (c.f. Seely Brown & Adler, 2008, Tynjälä, 1997, Laakso & Clavert, 2014, Leifer & Steinert, 2011). Informal or social learning means that learning does not happen only in the actual lectures or educational situations but in other situations as well (c.f. Seely Brown & Adler, 2008, Laakso & Clavert, 2014). Yet keeping the initail goal in mind: the intention of educating graduates who are as ready as possible for working life the understanding of how one becomes a professional in a certain field is not only about learning the substancebut also seeing oneself as a member of a professional community (Seely Brown & Adler, 2008). Through informal learning in the right premises for example in the case of Aalto University and Aalto Design Factory the goal is to enable students to adopt creative problem solving skills usually oocupied in the fields of design to other contexts (Laakso, & Clavert, 2014). The ways of enhancing such informal learning are keeping a low-hierarchy, proper informal spaces that are flexible an thus shelters different actors of academia and industry such as students, teachers, researcher and businesses. Also one important factor being the culture, community and climate that play a key role for keeping low hierarcies and informal activities including all the members of the community. This along with the possibility to mix free time and studies that may enhance informal learning that takes place outside the formal teaching settings. (Laakso & Clavert, 2014)

4.3 Problem-based learning

Problem-based learning, later referred to PBL, was first implemented in the 1960´s Canada. The intention was to bring a holistic approach to medicine studies by challenging students to integrate the theoretical studies into practice using problem-based learning concept. PBL is executed in small groups the intention being at getting the learners to work as independent groups where team members complement each other´s knowledge and former information. The problem in this context is meant to be the first push for students to begin the learning process.(de Graaff & Kolmos, 2007) It is suggested that problem-based learning is “a powerful transition process” (Savin-Baden, 2007)

Savin-Baden (2007) describes that for PBL the focus is not necessarily solving the problem but rather putting the attention on problem setting and problem-management without requirements on a solution. PBL may use lectures as a form of supporting but still the learning is expected to happen on the students own requirements. The learning outcomes are not set in PBL and thus learning is not guided in any certain direction. Still student are expected to have some base knowledge. Learning is considered to happen across the subjects from early on. Acting independently and ability to acquire information easily are however the qualities that are expected of the student through PBL. The difference with other concepts is that students ought "to see learning and knowledge as flexible entities" (Savin-Badden, 2007, p.9).

First and foremost thing characterizing PBL is its function as method of knowledge acquiring (Mills, 2000. The type of problem used is in PBL is often complex, ill-defined (Litzinger et al., 2011), a real life problem or a hypothetical one and the problem-formulation may be done by a student group or the teacher (de Graaff & Kolmos, 2003). The process and learning is done often in interdisciplinary group work (de Graaff & Kolmos, 2003) and student groups are put in a professional role (Fry et al., 2003, p.259-260). The groups ought to have high degree of freedom for example choosing their activities regarding their decision-making processes (de Graaff & Kolmos, 2003). In PBL teaching staff is meant to act in a role of a mentor instead of a traditional role of a teacher (Fry et al., 2003, p.259-260). It is suggested that not only taking the role of a mentor or facilitator but also the skills in coaching have an effect on students ability to pay attention on ongoing and meta-cognitive processes (ChanLin, 2008).

It is proposed that PBL method has several positive effects on student learning. Motivation is expected to be higher due to a possibility for students to integrate their own interests into the process as well as a possibility to act autonomously (de Graaff & Kolmos, 2003). Learning done through this method is seen as deep learning and is often done in a collaborative manner and it seems that student obtain higher cognitive skills in PBL (c.f. de Graaff & Kolmos, 2003, Fry et al., 2003, p.259-260). As complexity is built in the principal problem students handle students may get better grasp of complexity and connection in between concepts and principles in that certain context (c.f. Savin-Baden, 2000, de Graaff & Kolmos, 2003, Gijbels et al., 2005). Different skills such as communication and group work may be better learned through PBL (Gijbels et al., 2005, Fry et al., 2003, p.259-260).

There are some uncertainties in PBL such as it cannot be ensured that the knowledge and perspective that students get is as broad as possible and pieces of important information may be missing (de Graaff & Kolmos, 2003). PBL may prove itself to be more laborious and challenging for both students and teaching staff (Savin-Baden, 2007). Students ought to have a different point of view of learning in order to adapt well to PBL (Savin-Baden, 2007).

4.4 Project-based learning

Project-based learning, later referred to PjBL, has its roots in Denmark under engineering education in the 1970s. Industry during that time wanted engineers with new competence profile. The main idea of project-based learning was to carry learning by doing and experiential learning into the core of studies in engineering education. (De Graaff & Kolmos, 2007) The main difference in between PBL and project-based learning is that PjBL is aimed for applying acquired knowledge as PBL is for acquiring knowledge (Mills, 2000). Thus PjBL is placed in curriculum after the actual information has already been given to the student in some form and students are expected to have the basic knowledge to solve the problem (Savin-Baden, 2007).

What also differentiates PBL and PjBL is that students are expected to learn things clearly central to their curriculum and a project acts as a media for learning (Thomas, 2000).

Interdisciplinary work that aims for solving a problem and completed in groups is characteristics for PjBL (Savin-Badden, 2007). The problem or project type is cross-disciplinary, close to real life (Savin-Badden, 2007), solvable and implementable in real life (Thomas, 2000). In order for students solve the project they should to incorporate different principles (Mills, 2000) and theory and practice ought to be linked during the process (De Graaff & Kolmos, 2003). Students have high degree of autonomy and independence regarding actions, project management and decisions (c.f. Thomas, 2000, De Graaff & Kolmos, 2003, Mills, 2004). The expected outcome in PjBL is a solution or strategy for solving the challenge and it may be for example a report or a design set by a teacher (Savin-Badden, 2007). The role of a teacher is not a traditional one but a role of a supervisor or a tutor (Savin-Badden, 2007).

4.5 Design-based learning

Design-based learning, later referred to DBL, has its roots at Eindhoven University of Technology later in the 1990´s and it has influences from other universities, like Aalborg University. DBL aims to give students a possibility to develop themselves in design practices (Gómez Puente et al., 2011) and it has similarities with project- and problem-based learning for example centralizing student in the learning process (Laakso & Clavert, 2014, Clavert & Laakso, 2013). The focus is on designing solutions, systems and physical manifestations (Gómez Puente et al., 2011) and by doing so creating an atmosphere of creativity, professionalization, integration, co-operation and activation (Wijnen, 2000).

> *"A concept of technical university education in which students work co-operatively and actively on multidisciplinary design task, with the purpose of gaining qualifications as creative professionals capable of integrating all relevant aspects of education in order to analyse existing technical systems, to assess their quality, functionality and cost price and with the purpose of designing new products and systems with increasing performance"*[Towards design-based learning, W.H.F.W. Wijnen, 2000, p.5]

DBL the design projects or challenges may be described as complex, ambiguous, multidisciplinary and open-ended and they require hands-on actions to be taken in an authentic setting or a real life scenario. DBL exhibits some domain-specificity and some that generality regarding problem solving (Gómez Puente et al., 2011). Learning is expected to be collaborative based on enquiry of the situation and students are expected to do iterations for reaching a final design. The role of the teacher is to act as a coach and the focus of the coaching and feedback is among the solution under creation as well as the design process and action taken there. Reflection-in-action which is an expert action (Schön, 1983) is enhanced by the teacher facilitating and coaching through the process and thus enabling and encouraging reflections to turn into iterations. (Goméz Puente et al., 2013)

DBL seems to have positive effects on interaction, communication, motivation, teamwork and disciplinary expertise (Laakso & Clavert, 2014). However is is unclear whether the design skills practiced during DBL are actually the same ones that experts practice (Gómez Puente et al., 2011).

4.6 Summarizing learning in a design context

Universities are dedicated for science and distribution of knowledge. Learning in higher education should aim for critical thinking (Savin-Baden, 2007). However unfortunately it seems that the process of learning has been buried under the outcome-focused strategy (Saven-Baden, 2007). Learning should be seen as cyclical process that aims for constructing new knowledge for the learner (Tynjälä, 1997).

In design education the role of university can be described as a base in the journey of becoming an expert designer (Lawson & Dorst, 2009). Design as activity is a cognitive process (Lawson & Dorst, 2009) that according to Bloom´s revised taxonomy can be thought as the highest form of cognitive processes (Krathwol, 2002). Learning to reflect in an effective and productive way is seen as a good way of learning design among practice (c.f. Schön, 1983 & Lawson & Dorst, 2009). Creating possibilities for doing reflection and meaningful practice of designing could provide the base for design education (c.f Cross, 2011, Schön, 1983, Lawson & Dorst, 2009) alongside with a clear communication of the necessary skills for the design profession (Litzinger et al., 2011).

In engineering education capstone course have been one way of bringing engineering design and real engineering challenges closer to graduating student. Also other possible teaching approaches have been established in order to respond to the challenges of graduating student lacking skills (c.f. Crawley et al., 2007) – PBL, PjBL and DBL. What is common in PBL, PjBL and DBL that student has been brought in the centre, the learning is built around a challenge or problem and the learning is led by students. Differences are aim of each one of them – PBL is for knowledge inquiry, PjBL is for applying knowledge already possessed and DBL aims to provide design experience. These approaches take into consideration learning environment and social aspects of learning and take advantage of them in a positive manner.

Ultimately for creating a stable culture of learning the concept ´learning´ should be changed from outcome based into a cyclical and constantly developing cognitive process in the context of design.

5 Product development project –course

In this chapter the Product Development Project –course is presented. In this chapter the history, course´s blueprint, structure and teaching philosophy, intended learning outcomes and industry collaboration are presented. The description of the course is that of the year from which the student interviews are from.

5.1 History of the course

The Product Development Project –course has its roots in the 1980´s when its first form was established. The history is represented in table 8. The responsible teacher at that time was Matti Kleimola who came from the industry to work for the Helsinki University of Technology in the Department of Mechanical Engineering. He had on ideas how to improve the industry-university collaboration by using a project course as a tool to familiarize the students with industry projects. The course was designed for the mechanical engineering students who were at the end of their studies and the course was divided in to two sections: 1) machine design and 2) a student project. The expected outcomes for the project were a design and machine drawings for companies.

In the 1995 Kalevi Ekman was appointed as the responsible teacher of the earlier form of the course. During that year the project part of the course was separated and it got its own course code. In the 1997 the basic concept of the current PDP was implemented to the course and new expected outcome was introduced: a prototype. At the same time the course was offered to the industrial design students from the Helsinki School of Art and Design as a compulsory course in their studeis. In 2001 the first collaboration with a foreign university was initiated and also students from the other fields of engineering were able to take part in the course.

The development that has been going on during the years has been based on the practical experiences educated guesses on what might work in the course. The responsible teacher mentioned a few critical turning points in the development of the course such as the incorporation of industrial designer students in the 1997 as well as the international collaboration in the 2001. Those changes have been especially important for the course development and to its current form.

Today PDP is a course that brings together engineers, designers and business students, however it is open for students from other disciplines as well. It has a strong emphasis on hands-on doing, working with real-life projects and teamwork. Teams are multidisciplinary with an assigned student project manager and each student team works with a project provided by a sponsoring company. PDP is hosted by the ADF environment since its opening. The course has gotten a fair share of attention in the national media and is generally thought to be a success story.

Table 8 History of the PDP –course .

Year	What	Expected outcome	Participants	Credits	Team size
1980	Professor Matti Kleimola created the first version of the course.	Plans and machine drawings	Mechanical engineers	6	3 - 4
1995	New responsible teacher, Kalevi Ekman, was appointed for the course and the project part got its own course code.		Mechanical engineers	6	3 - 4
1997	The concept that is in use today was created. Collaboration with industrial design was started. Companies started to pay for the projects.	Prototype	Mechanical engineers, Industrial designers	9	
2001	First collaboration with a foreign university was started.	Prototype	Mechanical engineers, Industrial designers, other engineers	10	10
2008	ADF environment was launched			10	10
2014	The course today	Prototype	Mechanical engineers, Industrial designers, other engineers	10	10

5.2 The course blueprint

The PDP -course takes the whole academic year and is worth 10 credits, which translates into 270 working hours. The student teams are able to divide the working hours as they wish during the project. There is one responsible teacher for the course and one to two part-time teaching assistants. Since the course is held at the ADF premises more helping hands and coaching on different issues provided by the staff. However they are not assigned specifically to the course. In addition the whole complex of ADF can be used with the idea of “Need help? Just ask and somebody will help”. The course had roughly 190 students during the academic year 2012-2013 when the interviews were conducted. The number of students participating the course has been increasing since the course moved to ADF premises.

The PDP –course is part of the Product Development module included in the curriculum of Mechanical Engineering. The two other courses are called “Product Development” 5 credits and “Interdisciplinary Product Development” 5 credits. The idea of the module is to provide a broad overview of product development. Thus it is clear that the PDP –course alone is not the whole package. The goal of the Product Development –course is to provide robust knowledge on the product development processes, tools and methods. Interdisciplinary Product development -course aims to deepen the usage of those tools and enhance the importance of co-creation and to provide an overview of the other fields that walk hand-in-hand within the product development context.

The PDP –course is the last of the set and its aim is to apply first handed the knowledge the students have learned in the previous courses. However, on of the biggest difference between the students taking the PDP –course is that not everybody has participated the two previous courses and thus have not necessarily gathered basic of knowledge of product development. In practice there are many students who only take the PDP –course, which also may be their first contact with product development.

5.3 The course structure and teaching philosophy

In this chapter, the teaching philosophy as well as the actual events, team formation and deliverables will be presented. In addition to exploring the ADF environment and its importance for PDP is seen through.

Structure

The PDP –course is heavily based on independent teamwork, however it still does have some critical components on its process. The course had seven lectures, four checkpoint meetings, a PD6 –workshop, the Final Gala and a student debrief session. These events are shown in figure 11 as a timetable with a few additional events. In addition, during the course students were offered some extra trainings and workshops. Typically, at least a safety training for using the facilities at the ADF, performance training and facilitated feedback session are arranged. For the student project manager of the teams, separate trainings in project management are arranged, from which they get a separate course worth 2 credits by participating in all the activities.

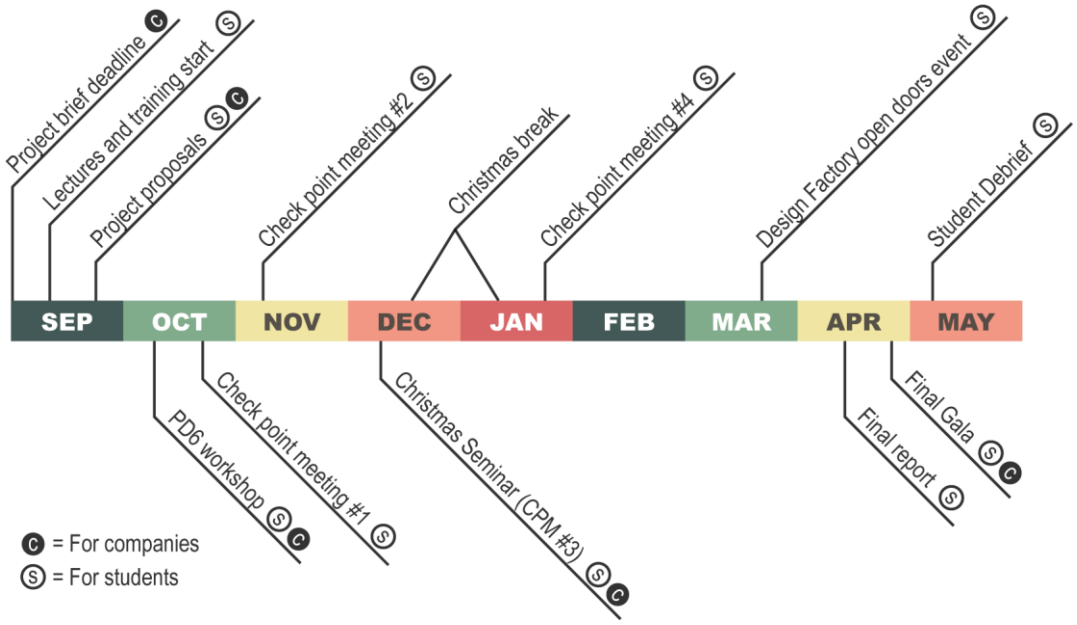

Figure 10 The PDP –course schedule in the academic year 2012-2013.

The lectures cover such topics as introduction of the course, project work, product development and inspiration. The checkpoints are for steering, giving advices and monitoring the progress. The first checkpoint is for observing that the student teams have started. Observed points are for example that the teams have started to have meetings, taken contact with their sponsor company and the general atmosphere within the teams is fine. The second checkpoint is arranged in order to check that something actually has been done, and the necessary paper work, in addition to

that the planning of the project and the project flyer should have been done. The objective of the third checkpoint was to show the other teams what has been done, and to practice presentation skills. The fourth checkpoint was organized in the spring time in order to see that the project is going forward nicely and is heading to a good direction. The course was finished with a the Final Gala where the end results will be shown in an exhibition open to anybody.

Project team formation

The team creation for the project was started with the selection of project managers amongst the students. In the academic year 2012-2013 the students who were interested of becoming project managers applied for the position. Out of these applicants the teaching staff selected 19 project managers and paired them with the projects based on the applications. All applicants had pointed out their favourite projects of all the offerings. After the pairing up, all the project managers got together for choosing team member for all the project teams. Everybody who was interested in participating the course, had to fill in an application form in order to be placed in a team. This was done to determine what kind of people was entering the course and what skills they possessed. The information was used to place the students in a right team. Project managers were asked to think what kind of skills they might need for the project and then choose the team members accordingly in order to form as balanced team as possible. The situation was slightly different for some of the remote members from the other universities who had been placed for a certain project before hand by the teaching staff.

Deliverables

The expected outcomes for the projects are a final working prototype that illustrates the features of the designed product. That prototype is meant to describes the idea of the final product and thus function as a nice way to communicate the final proposal of the product. The responsible teacher had noticed early on that it is easy for the students to make plans and drawings but to actually execute the product (may it be a prototype) was still is far more detailed and complex. Students tend to make more plans make more plans than take actual action which is one of the major goals of PDP.

During the project teams were also asked to document their work and at the end of the project they were expected to deliver a project report. The report was given to the teaching team for assessment as well as for the sponsoring company for ideas and as a document of the work that had been done. In addition the final report was meant to provide the students also the experience of reporting all the process and final outcomes to the “client”. The report length was not defined so as long as it gave a good insight on the process that the team had gone through as well as provided the information and insight that had been gathered throughout the process, it was considered to be sufficient. Of course the details and design information of the final prototypes should have been included. The limitations were few, which leaves more space for creativity.

Assessment

The assessment of the course was conducted at the end of the course. After the Final Gala the teaching team had a meeting with staff members from ADF who had been in direct contact with the team throughout the whole process. Also a few trustworthy students were selected among the students and they were asked to make a peer an evaluation during the Final Gala day. The grade scale was from zero to five, zero representing failed and five being the best grade. The evaluation

was based on final result, the general project work that is being observed throughout the project, learning of product development and communication.

ADF as facilitating environment and community

The facilities are an important part of the course as well as the community that ADF provides for the student teams during the course. The premises aim to enhance the interaction in between ADF community members and thus functions as a nice place for conducting user tests and such things. During their PDP year, the teams are an important part of the community and they are responsible for taking care of the facilities. For example each team is in charge of the general cleaning and organizing of the premises as well as arranging the community breakfast, that is held weekly.

5.4 Intended learning outcomes

In order to map the intended learning outcomes official sources were used and the responsible teacher was interviewed. The intended learning outcomes of the course have been divided into two different levels: team level learning outcomes and individual level outcomes and they are presented in table 9 on page 48. In order to make these intended learning outcomes comparable with the interview results as well as the professional design expert skills found in the literature review, the following illustration, found in figure 11 on page 49, was created.

5.5 Industry collaboration

The course is based heavily on working with sponsoring companies that bring the design briefs. Each company is asked to come up with a real-life problem that they have but for a reason do not have possibilities to investigate further. Preferably the topic is an open-ended challenge that approaches to “impossible”. However, there are also projects that are based more on incremental development rather than radical design projects. Sponsoring companies can be anything from start-ups to global enterprises and each company pays a fee of 15.000 EUR out of which each student team gets a project budget of 10.000 EUR. That money can be used for e.g. materials, necessary travels or external work, however the students do not get paid, as they are students working on a course project.

The participating companies have varied from big multinational companies to small start-ups that use their funding from the Finnish Funding Agency for Technology and Innovation (TEKES) for the project. Some of these companies have also taken part in the course as a sponsor more than once. The most important criterion is that they ought to be as open-ended as possible and the end results as a rule involves some kind of a physical prototype. The project may be even a service concept, a more classical mechanical solution or software. The project may be from business to business or from business to customer. The most important thing among open-ended setting is that the project is explorative by its nature. Some examples of the projects conducted in the PDP course (pdp.fi) a bike center sponsored by the City of Helsinki, people flow and the usage of Kinect sponsored by KONE, water sanitation challenge in Uganda sponsored by Unicef and a student start-up project developing a solution for doctors and patients communication

Table 9 Intended learning outcomes of the PDP -course collected from different sources.

OFFICIAL GOALS FROM THE COURSE WEBSITE	OFFICIAL GOALS FROM LECTURE SLIDES 13-14		RESPONSIBLE TEACHER´S INTERVIEW	
General goals	**Team goals**	**Individual goals**	**Team goals**	**Individual goals**
Understanding the quality of his or her own design, engineering or marketing skills	all the necessary development phases are complete and a prototype introduced	to become better aware of the quality of his or her own design, engineering or business skills	Get experience on project work	Reflection on one´s own skills and competencies
Understanding the potential and the challenges of interdisciplinary teamwork	by practicing project work in an interdisciplinary team students shall become able to	to understand the potential and the challenges of the interdisciplinary work	How to create a great team	Self confidence
Ability to carry out product development tasks by using both traditional and modern methods and tools	work out project plan & schedule	to understand how successful PD is based on both traditional and exceptional methods and tools	Meeting, negotiation, agreement situations	Reflection on what kind of work one likes to do and with whom
Understanding product development costs and economy	manage resources & risks	to understand Product Development costs and economy	Patent, agreements, NDA´s, IPR´s	To get rid of stereotypical thoughts and prejudices towards other professionals
Ability to deliver high quality oral and written reports	complete a project successfully	to be able to deliver high quality oral and written reports	Applied product development methods	To take initiative, be proactive, get rid of fear of failing and asking and take action
Being prepared for negotiations situations and to deal with agreements, NDA´s and IPR´s	communicate & document effectively	to prepare for negotiation situations and to deal with agreements, NDA´s and IPR´s	Carrying out a project from the start to the end - reporting, communicating with stakeholders	
			International collaboration and it´s challenges: cultural differences, time	
			zones and dividing the work within an international team	

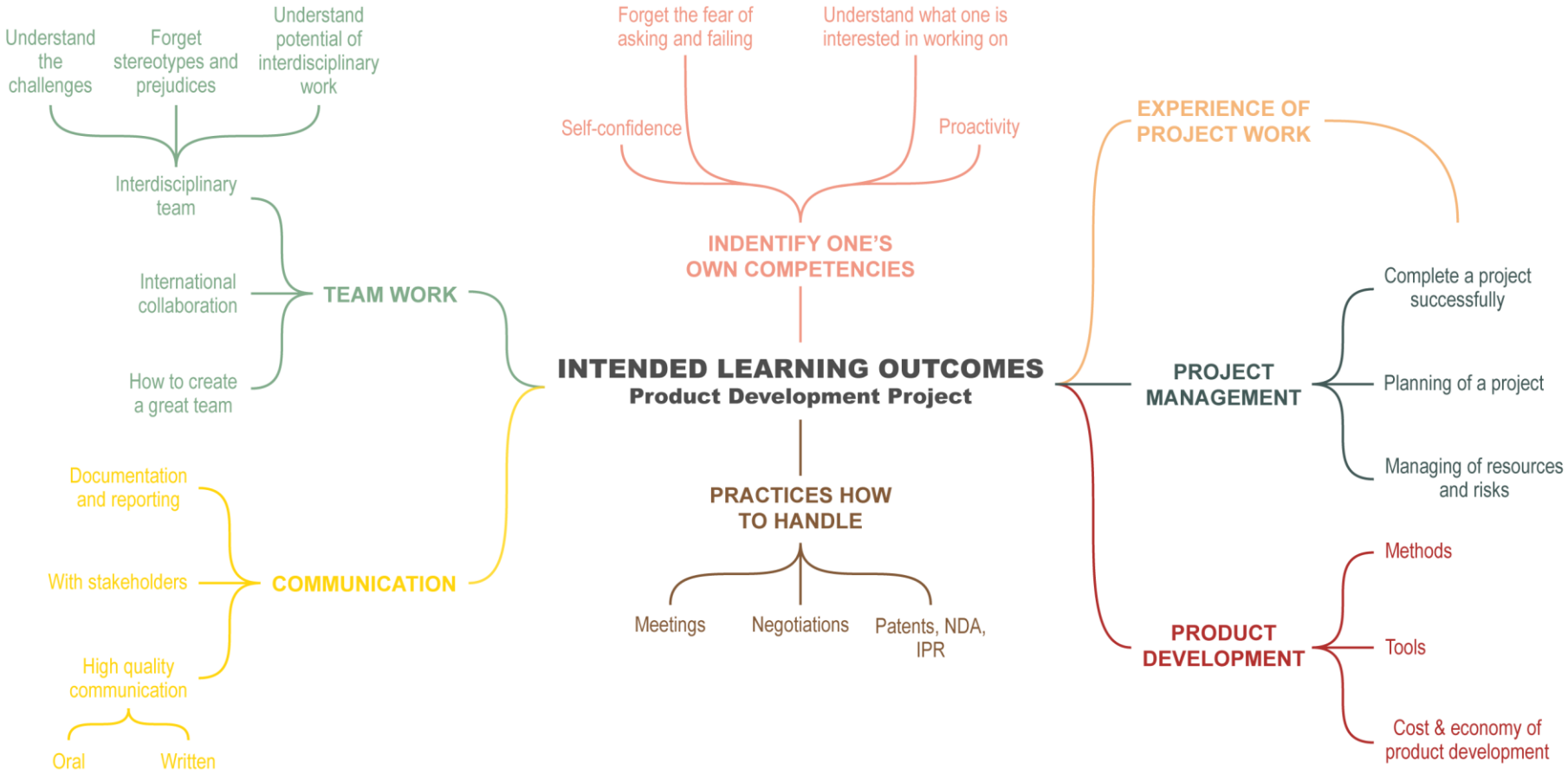

Figure 11 A compilation of intended learning outcomes

6 Interview results

The student interviews were conducted as explained in chapter 2. The interviews were divided into two main topics that the research focused on. First part was meant to discover the main learning outcomes for the students interviewed as well as meaningful moments and the second part was to investigate on the course practicalities and what of those practicalities were meaningful for the students and in the best case scenario to reveal some connections in between the learning outcomes and the course practicalities.

6.1 Learning outcomes of the Product Development Project -course

The learnings, meaningful outcomes and experiences for the students were in a main role during the interviews. From all of those matters either implicitly or explicitly expressed rose clearly four main themes that are categorized as follows:

1) Collaboration
2) Project management
3) Practicalities and approaches for product development
4) Mindset

These themes are presented in the order of the strength – thus meaning that collaboration was the most important theme and the practicalities and approaches for product development came to be the least significant. All the main themes identified include subthemes that describe the content more precisely.

Table 10 Segment divided according to the categories and interviewees.

THEME	SEGMENTS IN TOTAL	NUMBER OF INTERVIEWEES COMMENTED OUT OF TEN
Collaboration	130 Teamwork 100 Communication 47 Interdisciplinary work 22	10
Project management	55	9
Practicalities and approaches in product development	41	8
Mindset	38	8

In the following all the categories will be gone through with quotes from the interviews in order to enable more comprehensive view of the issues resulting from the interviews. All the categories were visible throughout the interviews and the themes created are strong and have strong connection to the course.

In table 10 the segments are counted for each theme. For the collaboration the subthemes have also been counted to present the significance of each subtheme. The total amount of segments for collaboration is not a sum of the subthemes as some segments may embody more than one subtheme. It ought to be noted that for example if one segment under teamwork has embodied more than one subtheme under that category it has been counted only once under the category of teamwork. An illustration of the interview results is found in figure 12.

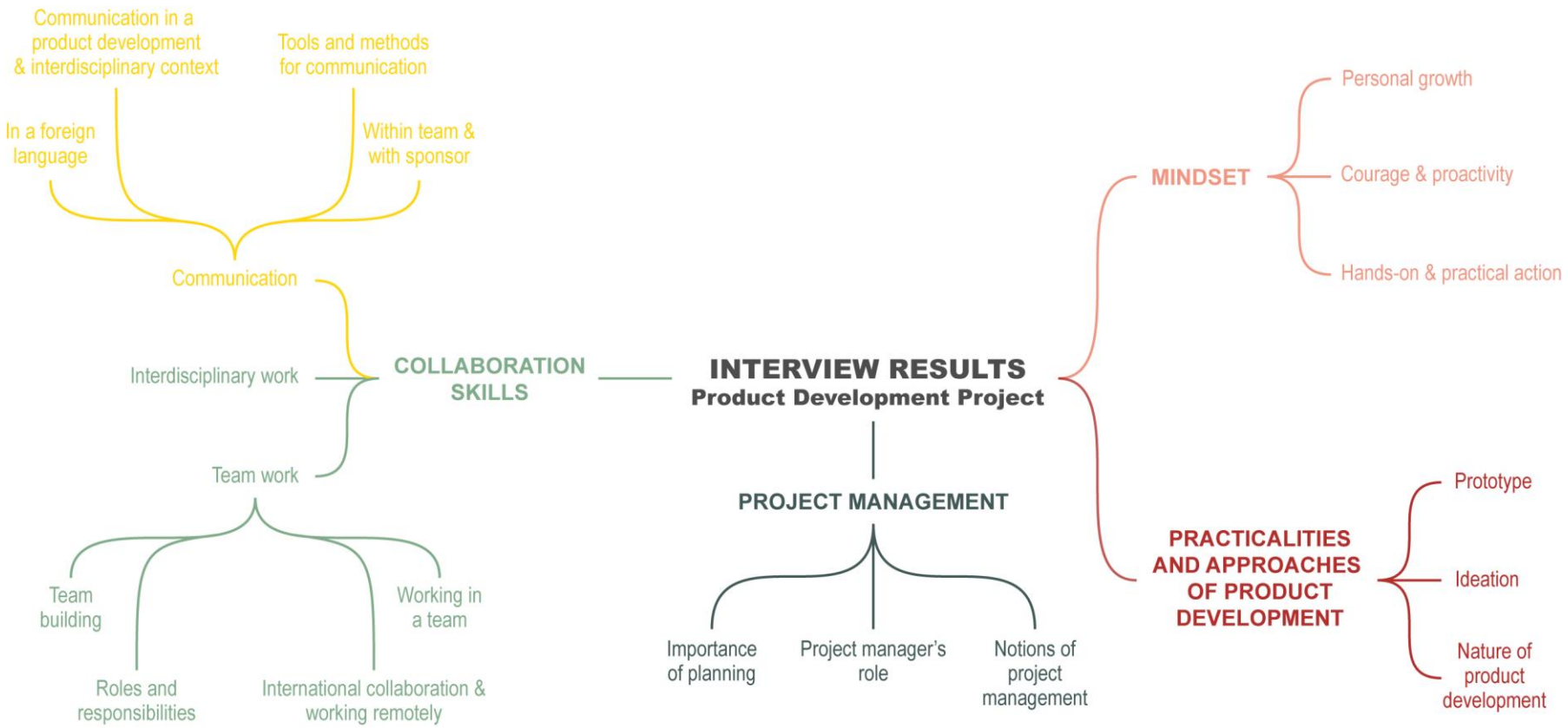

Figure 12 An illustration of interview results.

1) Collaboration

Collaboration is the biggest single theme that was identified in the analysis. This theme gathers some subthemes that are the following:

- Teamwork
- Communication
- Interdisciplinary work

Subthemes are presented in their order of strength and importance. Thus meaning that teamwork was the most recurring theme under the category of collaboration and international collaboration and working remotely was the least commented.

Teamwork

Teamwork was the biggest subtheme rising from the data. Teamwork has a big role throughout the course and thus the results can be seen here. Teamwork as category has also subthemes that are the following:

- Working in a team
- Team building and creating a team culture
- Roles and responsibilities in a team
- International collaboration and working remotely

Working in a team

Students described their experiences on working in a team. More than often it was about working with different people, fitting in that certain team and creating a space for all the team members in a team. Students commented on working with difficult team members as well as solving some interpersonal issues. Important issue was also finding the different personalities, the ways of working and fitting those in a one team. Importance of understanding how different people bring different things in that certain team and being able to motivate other team members was also a rather big subject of comments. Some students also commented on the difficulties that they had had in trusting and having confidence in others due to the different ways of working and acting.

> S2: "*[…]I noticed that people are difficult but at least in our team also very smart, difficult in that sense that we had some very strong egos and very strong point-of-views. And I could also say that very strong personalities. But on the other hand very smart and self-directed. So some people, when you give them a task to do, just do it and other people just are asking "What do I do now?" I noticed that when you learn to give space to people to work and when they come and ask something, I usually answered with a question or they themselves answered their own question and left content. Which for me was an important lesson about human resources, people do work when given enough space.*

> S8: "*[...]it feels a bit trivial to say [I learned] team working or working with different kind of people because in my case it wasn´t something new but you can always learn something new. And maybe especially team working in that sense that...people have so different interests and goals and balancing with those. [...]*

> *probably of team working, it´s a life-long learning ahead of you. But as I said, that even if I didn´t learn a golden rule book "This is how it works" but at least to notice what kind scenarios and things you might encounter. And to acknowledge others´ point-of-views and approaches.*"
>
> S7: "*[I learned...] also a strong confidence on what other people can achieve even though they are very different so as long as they have the same goal.*"
>
> S3: "*[...] for me it was that kind of slap in the face –course. Meaning that if you are used to people being very hard working and then here you meet those kind of people who don´t care. So that was something were you need to do a reality check that what life is really like. Not everybody works the same way."*

Students reflected their experiences on team work and identified situations where they had felt that team work had not been working properly. More often than not they did not have clear ideas how to improve those issues but they knew that those issues that they had encountered played a role in the teams´ success. Just as well they were able to pick up moments during the process where the team work had gotten better.

> S6: "*[…] on the other hand [in the future] I´ll encourage everyone to express their ideas freely then I´ll pay more attention to everyone´s attitudes and ideas.*"
>
> S5: "*Well I got to know how different types of people are and how different types of people are working also.*"

Team building and creating a team culture

Many students commented on noticing the importance of good team building, in most cases the lack of good enough team building and just as well creating a team culture that would enable clear ways of working among the team. Two main point were clearly identified under this topic.

The importance of team building was noticed from for example not knowing each other from the beginning and thus making the project going slowly in the beginning. The students reflected on their experiences on this matter mentioning especially that the team building should be done carefully and without worrying about the project itself.

> S5: "*We actually thought about doing one [team building event], but we didn´t find a date. The idea of team building is to build trust and also to bring the team processes to be faster. We think we worked well together, but especially in the beginning we worked quite slowly and we didn´t know each other very well, so that´s why you do team building, to work better together and to get to know each other.*"
>
> Later in the same interview:
>
> "*[I would change …] the beginning, it was struggling and because we didn´t do this team building or something where we really got to know each other. We were still unsure how people are reacting and we were soft so that no one gets offended because we didn´t know each other very well. […] The proper team building and in the beginning more intense phase where you get to know each other and how people work. And maybe even more not work related stuff. Because in this process [getting to know each other] that was very slow.*"
>
> S8: "*[…] it was probably related to team-building, having dinners together and other situations where you have conversations about something else than the*

> *project. It´s important that you get to know your team mates and it´s related to motivation and commitment, meaning that when you´re friends and getting along on a different level that makes you feel like you´re more responsible to those people.*"
>
> S7:"*And for us it proved to be one of our strongest things, our team really clicked. We spent a lot of time outside of Design Factory we would have a movie night and make dinners together. And doing that really helped us.*"

The team culture in that sense that a team would have its own identity, atmosphere of trust and agreed ways of working as well as tools was one part that to some students was very important. In all team working situations each team does create a culture of working in that specific team, these comments in this research mostly comment on that the students feel like, that the teams should have put more effort on creating a culture for the team more intentionally.

> S10: "*In the beginning create the rules for the team and don´t even think about the final product. Just agree on the ways of communication and what every team member wants to do and learn. It´s easy to think that that takes only like two hours but you should spend more like a day or two. Maybe the best way would be to go to a cottage, use sauna and make food together. Create a bond.*"
>
> Later in the same interview:
>
> "*The third success was here [pointing at a time of the project], so we got the rules created and smart communication or at least the basis of it [...]*"
>
> Later in the same interview:
>
> "*[...] I have a fairly good understanding of how to build a good team work, what it requires and what not to do. Or what should you do in order to the maximum out of people.*"
>
> S8: "*Maybe altogether if I were to change something I would have created a culture for the team right in the beginning: our own ways of working, rules, principles and as working together for one academic year is a long time, that would have made sense. Also maybe to map out why everybody´s there, what they expect and what do they want to achieve in the end in order to understand that we have very different ideas of the project"*

Some more specific comments were about the culture that was created around the project managers´ role just as well as some general comments of how a team was functioning. The project managers´ role as a topic is situated specifically under the main theme project management and will be covered in that section.

Roles and responsibilities in a team

Teams often have some kind of roles in them. Different teams have different roles but some things can be more universal than others. Students commented on some difficulties finding fitting roles and responsibilities for everybody. Some comments also regarded different needs in a team for certain roles for example a facilitator was mentioned couple of times. Responsibilities and having a clear role in a team seemed to have been not very easy task to complete. This topic crosses with the project management but the difference here is that students do not explicitly mention that the roles were divided – they talk more of the suitable responsibility and

freedom to act in a certain role in a team and thus completing a function and creating value for a team.

> S1: " *[...] to be conscious about your own place and role in the team and what you need to do. When there is no somebody doing the things you need to realize you yourself need to act or it won´t work. Or something might happen but not properly [...] So the roles and the responsibilities in the team need to be clear. Everybody knows what to do or at least what they should be doing.*"
>
> S7: "*I learned that you need someone to step into that role, otherwise you´ll be just talking for hours and hours. So the role of facilitator is an important role and someone should take it, it doesn´t have to be always the same person. If the group understands that you need one and if someone does it, then you are on your way to making more progress*."
>
> S6: "*For example I´m good at writing so I was responsible for the report. Or for example the Finnish members were better at communicating with the shopkeepers so they can be responsible for shopping*."

Sometimes the roles and the responsibilities were confusing and the team members seemed to give the responsibility to the project manager and thus deciding not to act.

> S4: " *If I need to point out the most negative [moment of the project] that would be to trip. We were there for 14 days and we worked during three of those days. [...] So I expected that if I were to leave with the project manager on a trip that we would work [...] I really wanted to get something done and we didn´t. So I really wondered why did we go at all […] Maybe I should have also in that point ask for the travel plan and so forth but I don´t know if that was really my job.*"

International collaboration and working remotely

In the course there are lots of foreign students as well as remote members from different universities from all over the world. This created an atmosphere of international working environment as well an experience on how is it to work in a team with remote members or as a remote member. Many of them reported challenges and difficulties already in the communication as well as delegation of the tasks and of course the most basic challenges were time zone differences and practical issues such as internet connections. Many comments in this category could be placed in different categories but it is seen valuable to take this as a separate unit as it is a big part of the course.

Very important came to be the communication, ways and tools of communication with the remote members. Students commented that it had not been sufficient and the importance of keeping the remote members in the loop and engaging them should be a priority when working with remote members.

A team member how worked as a remote member half of the project:

> S8: "*[...] I got that feeling that I wasn´t in the project so much.*"
>
> In the same interview:
>
> "*It´s very laborious for the team that´s in Finland to deliver all the information, it´s one huge job also.*"

In the same interview:

”*[In the future I would change] if there were remote members or if I were a remote member, somehow to keep that in the agenda up to the point of annoyance that do they feel that they feel that they are in and part of the project and know what is happening.”*

The lack of or the need of having more thorough communication was a clear challenge.

S4:“*We had a big remote team and we didn´t get everything out of it, not even close to, especially during the fall time. That was absolute a challenge. It´s nice to have a videoconference possibility but it requires more than a weekly meeting in addition. I actually didn´t know that there was nothing more than the weekly meeting […] nothing constant maybe one email but no constant communication.*”

S6:”*Then we tried to increase the number of meetings that we had [...] for example the remote member, we had for all of us, a responsibility to wake up soon to talk with him and hear his ideas – so he really feels part of the team.*”

Students felt that delegating task abroad, remote work as well as simply motivating and engaging remote members was a challenge.

S3: “*[...]how to motivate them[remote members] as you´re struggling with the same issues here [in Finland]of how to motivate people. It easily goes that you give them [remote members] a task to do and they still don´t do it. Unless they were here[in Finland] and part of the team. So maybe how to trust remote members [...] It really is about initiative, if a remote member is not initiative at all, you have difficulties.*”

S7:”*Also like engaging the international team members, as we had in Sweden, they were great but the amount of work they could do is limited because when you´re prototyping all of it needs to be in one place. […] And that was more like delegating tasks, we don´t want to tell them that just do this, but how can we ask them what they do to contribute. […] We found out that trying to have weekly meetings on skype didn´t really work. So we kept in touch on Facebook.*”

Cultural differences also rose during the project, sometimes escalading in bigger challenges, sometimes just not getting the work done.

S1: “*At that point there was rather interesting situation with our remote members [...] So some of our remote members thought that I should have taken more a leading role and to say one team member that you shouldn´t say that […] so those teams that have remote members should get their own cultural differences training session.*”

S4:“*[...] our designer was abroad but that made it difficult [...] we tried to use [him/her] but then [he/she] was in Finland […] It didn´t work at all the long distance connection. Designer has a very central role visualizing ideas and so forth so it makes everything interesting as that person is on the other side of the planet and doesn´t speak well English so it was difficult.*”

In the same interview:

”*Maybe a bit of stereotyping but when working with Chinese people you really need to ask whether they really understand. Everybody didn´t get that before the project was already far off. [...] when they respond ”yes, I understand”, you shouldn´t take it as that. But as you can´t know if that person´s English is even good enough, so it´s this losing you face, so you can´t know if they understand or not*”

Communication

Communication is something that everybody faces on a daily bases. Students found the communicational issues important. They reported that having and realizing a clear, self-explicatory and good communication is nowhere near to self-evident. It is a topic that has to be considered throughout any project taking into account all the stakeholders. Choosing the right media of communication for a certain stakeholder and giving enough information within the team as well as to outsiders.

Students also got wider perspective who to include in their projects, what interactions might be very valuable to their projects and how to communicate that to everybody. This did not only mean the outside stakeholders for a project but also within a team the different disciplines got their own meaning and ways of communication.

Communication has subcategories that are the following:

- Communication within team and with sponsor
- Communication in an interdisciplinary and product development context
- Tools and media for communication
- Communication in a foreign language

Communication within team and with sponsor

Students had found out that communication is challenging and the lack of good communication within the team and possibly with the sponsor might lead to less desired project outcomes. Speaking one´s mind in team situations and making ones thoughts explicit as well as understanding that communication needs to be constant to enable the maximum information flow to happen seemed to have caught the students´ attention. Also they acknowledged that knowing each other better in the team the collaboration got better and the communication got better as the project got further.

S6: “*When you don´t have good communication then you cannot manage and you cannot do anything of it to collaborate with each other.*”

S3:”*[...] so it´s just what I was talking about that in theory I have knowledge what communicational issues are but now I´ve been through them once and somehow managed to get to the end, so maybe that creates faith that when you encounter them again, you´ll manage.*”

S5:”*[…]we were soft and it was also like how we acted when we didn´t know each other and especially when you saw how we worked in the end. The communication was better and we worked faster as we knew each other better and the other one could understand.*”

S1: “*People assume too much, you assume too many things and don´t say everything as they were self-evident that you think the other person also knows.*

> *Even if that other person has no idea of those things. Especially if you have been thinking about something in your own head, so you think it´s very clear to everybody else, which it isn´t. Just as well as terminology may differ [between different people]. Different ways of communication, some people are more visual, some less. Also that you need open and repeat things that people understand differently. Or how did they understand what they just heard somebody else say because that might two totally different things.*"

> S10: "*[...] the communication internal and with the sponsor and in our case neither didn´t work[in the beginning]. Internal communication worked that way that me and couple team members were talking alone [online communication tool] and everybody visited that at times and were totally out of the loop. That was okey since we could see each other and explain what we meant and continue as one group forward. But the sponsor that was abroad, we didn't have contact with them and it was indifference and careless from both sides and from our side we didn´t want to bother. Which was weird solution, thinking about it right now.*"

Communication in an interdisciplinary and product development context

In this category some comments were related to communicating with team members from different fields as well as using visualization for communication and reasoning logically instead of just opinions.

> S7: "*[…] I didn´t know anything about mechanics, about engineering so I really learned how to talk, so communicate with like engineers and designers and kind of like they all need to be talked in a different way. […] then try to find words to say that in an engineering language and if they can meet you half way then that´s awesome.*"

> S6: "*Here I learned how to justify my choices. At the beginning we were saying that I like this, I don´t like this. […] Then we learned that we have to bring like reasons and engineering reasons why doesn´t it work or not just I don´t like it.*"

> S5: "*The different ideas, these sketches of ideas it was, that was something that I had never done before and it was interesting to see others´ sketches and these visualizations of processes to explain something and of course because there was this language barrier.*"

Tools and media for communication

Students found it difficult to find proper tools and media for internal and external communication. Trying to find the proper one for the team and then getting the team to actually use it seemed to have been difficult. They found it important to have tools for information sharing and communication.

> S1:"*I don´t know is it better to take more or less [communication tools] and then just clearly decide maybe even with slightly over ruling, that which tools to use. Everybody have their own likes and dislikes. Of course the platform should be*

some kind of a compromise. Then also that all the information should be in one place and not divided in many different places. But we didn´t find a perfect solutions or application. ”

S8:”*[...] we tried different project management tools for example Asana and Trello but Asana and Google Drive we used for sharing documents, it didn´t really work.*”

S10: ”*[...] we used skype [with the sponsor] but overall any voice over doesn´t really compensate for being in the same room physically [...] but the communication with the sponsor we should have started right from the beginning in the process and we should have been very transparent to them. We created a wiki-site but it was too late and they had no chance on commenting on the content so it was more like documentation.*”

Communication in a foreign language

Challenges related to working in a foreign language were part of communication issues. Some felt that it was a great experience but some commented on noticing clear challenges due to not being able to express ones´ opinion as comfortably as with ones´ own native language.

S9: “*International work community as we had couple remote members [...] so the work language was English so I noticed that the verbal ability that I have in my mother tongue wasn´t there, so it was difficult to describe what you wanted in English.*”

S6:”*[…] the one point was, because English is not our native language, sometimes we feel really short of words and we don´t know how to express our feelings especially. When you have a strong feeling, so you want other people to understand it*”

Interdisciplinary work

Interdisciplinary work that is in the centre of the PDP course came up in the interviews mostly as noticing the lack of a certain skills or the lack of an expert of a certain field. This shines through the reflection as the students felt that these missing skills and knowledge or a personages affected directly to the outcome of the project. Just as well there were clear comments on valuing the fellow team members and their knowledge from another field as well as their ability to carry out certain tasks or adding new perspectives to the project. Students commented understanding how different people from different fields might just have different words for the same things or they might just see the same challenge from different perspective.

S1:“*And the focus, what are premises in which you start to look at anything. For example the physical product, how does the designer see it, how does the engineer see it, how does the economic see it and you might have a lot of differences depending on whether the field is product-centred or profit-centred.*”

S6:”*In the beginning of the project, I said I don´t care about the designer, I don´t care what they say or like. But now I know, that that´s not true, the designer knows as much as engineer do but in different topics. ”*

In the same interview later:

"[…] usually we just think about how it [the product] works, if it works, even if at all. But the designers were the people who solved the problem in the end."

S7: "*[…]it is very valuable thinking through, even for a non-technical person to think through how we are going to assemble this [prototype] and the engineers go like ´oh yeah, how are we going to assemble this?´ So the stupid questions are not so stupid*."

S8: "*[...] and one challenge was that we didn´t have a designer. Our designer was abroad it [he/she] wasn´t what we needed, so practically we had no one who could have visualize our ideas very well, which was quite a big challenge as we worked based on concepts. That´s we we had to outsource all the visualizations and concept descriptions*."

S10:"*[...] we had a clear electronics or control guy so the project came to a halt often on that side. So we weren´t able to develop those sides that otherwise could have been more developed.*"

S2:"*So if we think about the final outcome of the project, it really sucked that we didn´t get [him/her] [a designer] because [he/she] was an incredible designer.*"

2) Project management

All the interviewees had comments about this theme regardless of their role inside their teams. The importance of good project management and planning seemed to have been clear to the students after doing the project. Project management affects everybody in the project so it is very visible theme for all the team members. The students seemed to understand the value and role of project management and especially importance of good project management.

Students also reported often the lack of good, thorough and anticipating planning. This caused at least the students interviewed to grasp the idea what needs to be planned and sometimes up to what details should be planned. As well as sometimes understanding that even when something is planned the things actually realizing might not follow the plan for one reason or another.

- Notions of project management as part of a project
- Project manager´s role
- Importance of planning a project

The importance of the role of a project manager became relevant and seemed to get quite a bit of attention, especially in those cases that it had not been done in the interviewees mind perfectly.

Notions of project management as part of a project

Many students had comments about project management as a general notion. The students did not have a golden rule how to improve the things that had maybe gone wrong but they commented on themes like work load and role distribution, usage of project management tool and noticing generally the importance of project management.

The most common comments in this part were comments of distribution of the roles and work load. Most of the students had noticed that more often than not it had not gone ideally and they would in the future take it more into account.

> S8: "*[...] at the beginning we tried giving out clear tasks, the project manager gave them, but not to one specific person, and I think nobody took those tasks personally and nobody felt responsible for the task. Ja then again is it the right solution either to give out tasks to someone because that leads to the idea that project manager tells you if you have to do something.*"
>
> S10:"*[...] another thing that I learned is that project management is important part of the project and it leads to a lot of frustration if the management is careless.*"
>
> Same person later in the interview:
>
> "*[...] At the concept phase we probably could have done work more separately and more divided. We were one of the least teams that split the team into sub-teams, so that could have helped us to work in pairs or in smaller sub-teams.*"
>
> S4:"*[...] at least all the project management stuff and what you should take into account*"

Also some direct comment very made on the project management tool used and how those tools worked. General opinion seemed to be that the tools were not used to the maximum as for the effect that they had in the project.

> S4: "*And even if we weren´t in troubles with it in the end but the documentation and reporting, demanding those as it is more difficult later*"
>
> S3:"*[...] if you think about for example doing the project plan and so on, so you´ve always known that it´s good to have a good plan and use it, but we didn´t really use it. I went back to it maybe twice when I had to. But no, in my team we didn´t use Gantt chart and in the end it was clear that we hadn´t used it*"
>
> S8:" *we tried different project management tools for example Asana and Trello but Asana and Google Drive we used for sharing documents, it didn´t really work because everybody didn´t use them. And of course we had a lot of meeting notes in [Google] drive and you went through them at times but it´s very difficult to understand what they had discussed about if there´s only some lines written..*"

Project managers´ role

Project managers´ role was clearly one issue that rose as a commented subject. It rose many things to everybody´s mind and reflected often what had happened and how things had been handled in the project. In the course it seems to be a question whether the project manager is leading the project, acting as a good or a bad leader – what are the qualities of a either of them, if the project is going under too much hierarchy and if the project manager seems to be incompetent or not. The role of the project manager seems to be very contradictory in the course and how it seen depends on the team and also on the individual.

More often than not people were not pleased altogether with the way the project manager had been acting, with one exception. They felt that the project manager was either not leading enough or too carefully or that (s)he was dictating.

S4:“*Regarding this project manager´s incompetence we tried to fix it so that I talked with [him/her] during our travel together about the issues concerning our team. We were there alone the two of us and I talked before, during and after the trip but nothing changed. Then we created a shadow organization that included me and two other team members, and we were like: let´s do this. So basically we steered at times our project manager, organized things on our own if [he/she] had not thought about something, so we took care of it. It would have been tough to cycle everything through the project manager without benefits and we had tried that before. We had tried to teach [him/her].*”

Later in the same interview:

“*[…] thinking it through now, project manager´s role is very demanding. So if I ever will be a project manager, I would spend more resources and time on planning than what our project manager did now. So at best you [project manager] don´t have to do much but […] on the other extreme you have to do yourself instead of using your time organizing, you do somebody else´s work, who left it undone. […] So project manager needs to stretch to everything.”*

S3:”*[...] you´re a dictator or if everybody gets used to that, that the project manager needs to give out tasks, no one ever starts to think for themselves or starts acting on one´s own initiative. So that also creates challenges quite a bit and I got feedback from my team members that I should have been stricter and just make decisions. But that is pretty much against my own philosophy if I would have acted like that, it would have just embraced the standard normal way [instead of embracing one´s own initiative].*”

S8:”*[...] one more challenge was that we had this hierarchy. So people thought that the project manager will handle [everything] but the project manager is just a contact person in between the teaching staff and the sponsor and someone who put the team together. But the project manager has not gotten different education nor is [he/she] any more different than anybody else in the team. It is easy to think that project manager takes care of everything and tells everybody what to do, so there is a lack of one´s own initiative.*”

S6:”*[…] maybe because our managers´ approach, of course we followed what he wanted us to do. We had some kind of meetings but usually the manager was the person to lead the group. So he had a strict way of thinking, some ordinary things, just school courses.*”

Later in the same interview:

“*The main thing was that he was only saying his ideas, really pushing us to that idea. And it was difficult to convince him that he´s wrong. And these ways took little bit of time and effort.* ”

The one exception:

> S7:"*[…] then [project manager] would bring cookies and snacks and [he/she] would just be there to encouraging and congratulating and saying that yeah it looks great and giving the feeling that you´re not alone working in the basement*."

Importance of planning a project

Importance of project planning was commented surprisingly much. Some students were not sure whether to plan more or whether to have more creative chaos, other had found better way to plan the work during the project what was in common in all the comments was that it some relation to time and managing the time.

> S1:"*[...] always if you don´t have any deadlines nothing happens and you get no decisions made. Then when the deadlines get closer you just have to push the decisions through, whether good ones or bad ones, just to get forward. And how to have more planning, even though in the beginning of the course you have no idea what it is going to be like, so you can´t plan it all. Thinking about it now, it would have been great to have weekly plans and deadlines but no one had the will or any great vision how to do it, so it wouldn´t have been realistic nor reasonable. Well deadlines and haste create results. So we could have had more deadlines and steps.*"
>
> S3:"*[...]we didn´t have any plans ready […] I think that is a concrete example of how we are told that do this and that and when you don´t do it as suggested, you find it out in the end that yeah, we should have planned the budget better. […] so trying to find the fine line in between actually doing and planning. The outcome maybe could have been more coherent if we had really planned more…"*
>
> S6:"*Then of course we had a project plan from the beginning but we weren´t really caring about it. It was kind of a very big periods for each phase so the time constrains weren´t really and we didn´t care about it too much. But on January we thought that we have to speed up. Then we had to think about how to distribute the work, because it wasn´t of course something that could be done with just one or two people, everyone had to collaborate.*"
>
> Later in the same interview:
>
> "*[…] actually we talked about timing and deadlines in those meetings that we had in January. We revised our project plan and it was nice to see that like at January and February we had planned the time so nicely that everything was finished really in time. And this kind of encouraged us in the rest of the project […] then we saw that this kind of planning works, we decided to continue it for the rest of the project. So before March, for March we had very detailed time plan maybe for every two days, we had tasks that had to be finished.*"
>
> S7: "*And really the value of planning, because before we do a student project it only lasts like a month any way so really what there is to plan and does it really matter if you stay on time. But in a nine month long project and ordering stuff from overseas it´s a different thing. So overall why would you plan a project.*"

3) Practicalities and approaches in product development

Collaboration is the biggest single theme that was identified in the analysis. This theme gathers some subthemes that are the following:

- Prototype
- Nature of product development
- Ideation

From product development point-of-view, students commented on understanding the basics of it. Prototyping and ideation were the two main topics that rose in the interviews to be the most important ones. Prototyping was commented to be a good way of communication as well as enabled the students to try and see things for themselves. Ideation had more mixed impact some students felt that it had been more waste of time, inefficient and difficult as some other students reported that it had been fruitful and they will use ideation techniques later on.

Prototype

Prototyping was the single most important feature that rose as a theme in the interviews as one of the product development tools. The comments were very general just mentioning that they felt that they had learned to prototype.

> S5: "*Well for product development courses the rapid prototyping. I didn´t know a lot about that was something new that I learned in the PD6*"
>
> S9: "*[...] about prototyping I hadn´t done anything related to it before neither had the two other mechanical engineers in our team. Something on our own, yea, but now you had to produce a functional model, so that we hadn´t done before and it was new. In practice it was that we were playing with Legos but everything had to fit together.*"
>
> S2:"*Yeah, I learned how to make different kind of prototypes. From prototypes made of paper to acting as well as physical models and everything possible and this was something that I couldn´t have learned elsewhere. It has been really cool to learn how to make quick and dirty prototypes and to see early on what directions you can take […] making those quick and dirty prototypes was probably one of the courses most useful things among other things.*"

Nature and process of product development

Most of the comment about the nature and process of product development were general comments that students felt that they had learned some key features and the process of product development. Some comments regarded the user-centricity in product development, how to choose, what is important and the value of interdisciplinary work in the product development premises.

> S5:"*Yeah I didn´t have a clear idea of product development in the beginning, I had a lot of this from this former aspect what´s the processes that you have.*"

> S7:"*[...] for a product so the whole process, who are you, what are you doing, why are you doing it, who are you creating this for, who is the user, what are their needs …*"
>
> S9:"*[...] maybe the product development itself from the start to the end. In the beginning I had no idea about it and in the end we had functional stuff coming out.*"
>
> S6:"*And I learned the key features in product development, what are the important factors like feasibility, viability, those that are kind of unknown to me. That from the company point of view, what should I take into account.*"

The comments above are the most common and general comments. Then below there were few students that commented on something more specific related to the nature of product development.

> S7:"*[…] from this one I would say that I learned that it´s better to have 90 percent good product to deliver today than 100 percent perfect one to deliver in two months just to keep the project moving. Doesn´t have to be perfect just like anything works, like what is good enough.*"
>
> S10:"*[...] the user-centeredness was something positive in the beginning, even though it was difficult to communicate it [the importance] to the team. Even to myself it was hard to reason why we need to talk to someone, why we can´t just start coding […] but in the end it was a good thing that we did [talk to other people] and at least you learned different ways of doing things […]*"

Ideation

Ideation was the only direct method or phase of the product development process that students specified in the interviews. Mostly the comments regarded that they found the ideation methods very useful – if they used them and a few comments regarded the not so successful ideation, reason of failure being either in demotivated team members or unorganized ideation methods.

> S8:"*[...] these ideation tools and methods I´ve used elsewhere also. We do need structure in those things also. As free as brainstorming is but if there is no directive factor and limitations, it easily just goes into a chaos.*"
>
> S10:"*That was also kind of a big thing that brainstorming does work but it´s not efficient […] just multiply the time used [on brainstorming] by 0,1 and you´ll get the efficient working time. So in one hour that is six minutes of actual working time. For a lot of people it is easier […] if you think about it [the topic] on your own before you start talking about it together.*"
>
> S5:"*I got to know new ideation methods which I most likely will use.*"
>
> Later in the same interview:
>
> "*We tried to use different methods, e.g. writing ideas to papers or time travelling – how would you do it if you were in the middle age or something like that. We tried to use this stuff but someone thinks that he can´t do it or is very negative of the topic is blocked even if you try to get people in them, sometimes it doesn´t work.*"

4) Mindset

Third main theme was a mindset. This category rose slightly unexpectedly in the data and was sub-categorized in the three different themes:

- Courage and proactivity
- Hands-on and practical action
- Personal growth

In the interviews students reported to have to ask for something from somebody more experienced or looking for somebody just for reflecting what is going on as well as asking for advices. They also felt that they have more courage to be up and front about their projects and asking for help and advices outside the ADF premises. The students showed to some extend proactivity and courage in order to get the best possible outcomes for the projects. In some cases the reflection came up in the interview as the students commented on that maybe they should have asked for help.

Many students also commented on finally getting to do something with their own hands not just talking about theories or ideas. They were able to try out things within the project and see how they actually might work in real life instead of just guessing.

Courage and proactivity

Courage and proactivity concluded often as opening the project to outsiders and asking for help. The students commented on asking for help from outside experts, from the teaching staff and possible project stakeholders or users. They felt that it had been either important or that they should have done it in order to get more out of the project.

> S6: "*Then I learned to be in touch with the staff more. Because I´m usually that kind of very silent person working on my own. I don´t like to bother the staff too much but then I learned maybe in this course that the staff really wanted us to be in touch with them.*"
>
> S7: "*For the user interviews, I´d say to contact people early, not to be shy to be prepared but not to be afraid that you´re not professional enough or even if you have a dumb thing as a prototype, but make it worth their time but don´t be ashamed of what you have and ask a lot of questions and really listen to them when they criticize, to not to be offended but to be open.*"
>
> S10: "*Experts´ help [...] this is what I talked earlier about. Understanding that you need to ask for help not just get frustrated on your own. This is to me still, as we have Google and everything nowadays, that I don´t want to bother or look stupid asking something. Even though people with some sense inside their heads, when someone comes and asks for something, understand the situation and don´t think you´re stupid […]*"
>
> S1:"*[...] the most important is knowing how to ask for help. Contacting outsider […] you don´t have to feel nervous, so just look into who are the experts and contact them.*"
>
> Later in the same interview:

> "*There is a point that you don´t know anything, you don´t even think about knowing anything [about the project topic]. So at that point there is no other option. Of course it makes your life easier if you boldly asked for help.*"
>
> S2:"*[..] there was a lot of it [help] available but our challenge was that we should have known how to ask and accept the help. So now afterwards thinking about it, yeah we could have had a better project and we would have learned a lot more, if the staff would have been involved more.*"

Personal growth

Some students had some very reflective personal things thought through from the course. Every student had of course something very different that they had learned about themselves.

> S7: "*Now I have my own business, so I feel that now I can offer a lot more solutions and what types of solutions.*"
>
> S1:"*[...] my own life´s management and fitting everything in this.* "
>
> S10: "*I also learned that [...] I need to stay quiet and let other people talk at times and just listen. […] I had difficulties with that at times, when I heard the first couple of words I thought that I knew what the other person was talking about and I started to talk. That´s not good.*"
>
> S6: "*I´m a very strict person and I couldn´t really tolerate that some people didn´t attend the meetings and then I was really like insisting that we have to decide on these people but then I learned that if we don´t care about it too much then gradually it will solve. Or at least you should wait until everyone feels the problem, not just you feel something about it.*"

Practical hands-on doing and practical action

The actual doing, instead of just talking and thinking about theories is on the core of PDP as well as just solving the problems at hand. Students commented on the best part of the course was the practical doing and creating by doing. Just as well as just pushing through the problems, whatever they may be.

> S1:"*The hands-on doing, actual doing not just talking about it. That´s the best [part of the course].*"
>
> S3:"*[...] maybe PDP taught [me] that just do and try and be open to new things. It just might be enough that in the future you can just go without being as nervous about it [about successfulness] as before.*"
>
> S4:"*That [I learned] that if something goes wrong, doesn´t matter you just need to go forward. You can´t stay on point fingers at people, doesn´t matter, go forward. That kind of attitude.*"

6.2 Course practicalities

In the interviews when asked from the interviewees about the course practicalities these topics came up. In the table C it is shown how the segments divide in between the different course

components. The more segments one component has gotten from as many different students interviewed represents loosely that its´ significance to the students. For example the course book was mentioned seven times during all of the interviews by four different students. It is thought that the more a component occurs in the interviews without directly asking the more significance that component has in the students´ minds.

Table 11 Course practicalities segment divided according to amount of segments and interviewees.

	SEGMENTS IN TOTAL	NUMBER OF INTERVIEWEES COMMENTED OUT OF 10
Component		
Book	7	4
Lectures	15	6
Workshops	14	5
PD6	10	5
Checkpoint meetings	4	4
Gala event	6	4
Support		
Teaching team and staff at ADF	39	10
Sponsor	21	8
ADF facilities	15	6

Course components

As introduced in chapter 5 Product development project – course the courses consists of certain elements. These elements came up in the interviews to some extend that will be further looked at here. Some of the components seemed to have been more meaningful for the project and process considering the frequency they came up. The table of the comments is shown below.

Book

Only seven segments were in total by four different people out of ten regarding the course book. The comments mostly give the impression the book was either forgotten or used in a lightly manner.

> S9: "*[...] we had this one guys who had read the book so [he/she]had an idea what we should have done. But to my understanding we didn´t follow the book, more like did it our own way*."
>
> S6:"*We used the book. I´m not sure if that´s the course book or not. I don't know. But yeah, when we were comparing ideas we used the book to see criteria for feasibility, viability and so on to compare that. And in the beginning we had kind of an education officer and she read the parts of the book and reported it to the group […]*"

Lectures

Eight students out of ten interviewed commented on lectures at some point during the interviews. Some students had not had time to really go to the lectures, some remembered certain lectures. However these comments suggest that the lectures are not the main point in the PDP course.

> S7:"*I remember a few of the lectures especially understanding the user and communication. Those were really important changing our thoughts about user interviews and user testing. Those lectures were very important and useful for us*."
>
> S5: "*They [lectures] were nice but not helpful I would put more content to the lectures. I remember now that they were mostly images that what was happening before [in the course], that was an idea and I felt that there wasn´t really content. There´s more theoretical content to product development and it might be that there is one course one semester that maybe part of this content would be in PDP*."

Workshops and other non-obligatory activities

During the course some non-obligatory workshops were provided to support on certain themes. Team can choose which to take part. In total five students commented on remembering having some workshops provided during the project. Most of the comments either commented on a certain workshop that someone had felt had given some extra knowledge or not taking part on the workshops.

> S5: "*[…] also there were some workshops, where I couldn´t take part, maybe because they were in Finnish or that I didn't have time […] Then this presentation training I took part. That was very interesting, that´s something I learned – some new stuff how to present stuff*."
>
> S4: " *[...] for this [big challenge in the project] we could have gotten help here [at Design Factory] but we skipped that thing that was almost obligatory and had something to do with the team work*."

PD6 – Product development in 6 hours

Six out of ten students commented especially on the PD6 workshop that was held in October. All the comments were positive. Major theme in all the comments was that it had been an important moment for the team especially team building –wise.

> S5: "*[…] and PD6 was a very good experience. It was team building and working with the company representatives. […] with PD6 it was a good start and you have somehow this whole process with all the steps. That was something good[…]*"
>
> S4:"*[...] PD6 was a good thing as you have it in the beginning, so you get the feeling that you actually do something hands on. And also it brings the team together if that had not been successful before that. [...] so it makes you work together at least for six hours straight.*"

Checkpoint meetings

Only four comments were collected from four different students.

> S5: " *And the checkpoint meetings, which I think is a good to keep track on things, that there is some action to the course staff that they can see what is happening in the teams, still it is a course. Also there were points where we could get feedback, well you could always get feedback from anybody if you wanted to ask, but that was more official point to get feedback*."
>
> S4:"*[...] then we would have these checkpoints but it felt like you would just pass them, or you wouldn´t get any negative feedback even if you had made no progress*."

Product Development Gala

The final presentation and delivery day is Gala day and that got six comments from four students in the interviews.

> S4: "*I think it´s a great thing to have all the parties [Gala] and so forth.*"
>
> S7: "*One thing, the Gala was really great. It was really good experience and we wanted to get a lot of publicity out of it*."

Support

An independent design course like PDP of course provides support to its´ students. Now the students were asked lightly if they felt that they had gotten support and where they got it. This part was divided into three different parts that are the following:

- Teaching team and the ADF staff
- Sponsor
- The facilities at Aalto Design Factory

These three categories also represent nicely the support that the students have been expected to get during the course.

Teaching team and the ADF staff

The students had quite many comments about the support they felt that they had gotten during the project. Most of the comments were positive and reveal many different ways that the students get support from the staff at ADF. Students commented on getting help in anything that they had felt need to get help on – whether they needed help with the sponsor, prototyping, process or team dynamics. Also students would get tips, suggestions and they would be guided elsewhere for support and help if the ADF premises would not be enough. The atmosphere and the presence of the staff came up also – students mostly felt comfortable going for help and knowing that they would not be overlooked.

> S5: "*Also from the staff side, they knew a lot so usually when we needed something we found help from them.*"

S1:“*The staff was really good, helping always when they had to time adn you would get help when you need.*”

S4:”*[...] the professor just came up with couple of names straight away, that contact these people in the campus. So if there is something that you don´t have here [Design Factory] and you have a lot of stuff here also, you would get straight away an answer where to go to.*”

In the same interview:

”*[...] a lot pf the goodness in here comes from the relaxed atmosphere [...] so meaning that I can just go and talk with the professor, even when I wasn´t a project manager, and you would get the feeling that the professor really cared about what you were saying […]*”

In the same interview:

”*[...] somehow very early on I got the feeling that if I were to need something for PDP, I would get it from here [Design Factory]. I don´t know how that atmosphere was created [...] that I can always ask for help.*”

S3: ”*[...] that meant a lot when the professor came to see us late at nights to see what we were up to.*”

S10:”*I think it´s a good thing that the teaching assistants are available almost 24/7, so always when you sent a message they would answer very quickly.*”

In the same interview:

”*Then of course those experts at the electroshop [in Design Factory] were a great help.*”

S8:”*[...]so the teaching assistant held [sessions] and gave tips what tools we could use [...]* ”

Some comments however were about feeling like discrimination and ignorance towards some teams.

S6: “*I think we didn´t have much help from the staff side so in the end we went just our own way […]*”

In the same interview:

“*Then in the gala and also in the presentations not just me but many people had kind of feeling of discrimination, I can say, or tendency towards some groups and we weren´t happy about it. I mean maybe visibility was kind of important issue in this course that the groups had to be visible. So that their work was really seen. So it´s like considered during the whole project but then maybe some groups were loud and every time talking about their projects or in close contact with the staff […]*”

Sponsor

Some comments related with working with the sponsoring company. The comments described working with a supportive mentor-like sponsor as well as customer-like relationship. Students

talked about having or involving the sponsor in the process, some mentioned that the sponsor should have been involved more. Some students felt that they had not gotten enough information from the sponsor. They also noticed that they had had good and extensive contact with the sponsor or that they should have had more contact with the sponsor.

> S6: "*[…] in the beginning we had a training session over there so they explained everything to us, either from the users side and how does this machine work, what are the problems, what are the costs. I mean whatever we had to know about it. And during the process they provided us with some materials.*"
>
> Later in the same interview:
>
> "*[…] the contact person […] was really helpful and encouraging. That was really nice, I mean he was not like any company, he didn´t underestimate your work or anything. He was really positive about the project every time he saw some progress- He was also realistic, for example whe we finally went to test our prototype we ourselves also saw that it had many shortcomings but he was very patient. […] He was very patient and he was giving very good suggestions how to solve the problem. Or like saying where should we focus our attention especially here [a moment in the process] where we really were indecisive.* "
>
> S7: "*So just basically working with our sponsor and how to make sure that we were enough in contact. So that it doesn´t get to be maybe too long and they have a negative surprise coming up. But rather when there is a problem, tell it straight away. Of course trying to solve it on our own but rather be up and front about it, even if we made a mistake so that it doesn´t turn into a snow ball or a really big thing.*"
>
> S5: "*[…] we were really lost cause we didn´t get information from the company because they didn´t want to limit our creativity but somehow they communicated with us that they have something great behind it, but in the end they didn´t really have much.*"
>
> S10:"*That kind of moments of failure or that nothing was good, so at least we failed at taking the sponsor part of choosing the concept. We made the decision and we didn´t theirs.*"

The facilities at Aalto Design Factory

Mostly students felt that ADF provides nice setting and environment for the PDP course. They appreciated the space and the general feel of the place and felt that it gave the support that was needed. Just as well as different people at ADF and the opportunities to meet, the space is good for prototyping, testing and meeting your possible target group.

> S2:"*[...] so in its own way this [Design Factory] is an inspiring environment. So if I think about doing this course in the boring Tuas-building, it might not be the same. For example people would not get as excited […]*"
>
> S5:"*I would say that it was that you could speak to anybody and get feedback, I was mainly talking with other team members from other teams. You could change ideas and what are their stages and that was something nice. Design Factory is a very good place to have this [course] where you can meet and prototype, you have from Legos to welding, everything here.*"

Still you cannot serve everybody, in this research one student commented on that they had preferred finally work elsewhere.

> S6: "*We started to have meetings outside Design Factory because we all bored to coming to Design Factory to working strictly and in those informal meetings [meetings that they had elsewhere] we could really work more efficiently. […] for us it was like when you have a course and you just attend that course and come back home, so because we had to come to Design Factory every week at the same time for many weeks then we were bored of doing so. So yeah we decided to change the location.*"

6.3 "This helped me to learn!"

The students were asked how they felt that they had learned during the course. This category is not directly answering the research questions but it does give some insight about how the course works. The comments contain students´ experiences on what enabled them to learn something in this course. Six interviewees out of ten were able to give some comments on the subject total amount of the segments were 17. Most of these comments were unspecified on what one had learned but simply what had helped her/him. The comments mostly describe on the practical side of learning. Most recurring was peer learning the students felt that they had learned from their own team members. Other points were doing something practical and hands on and having no other option than to make the situations work as well as one´s own reflection.

> S10: "*In this course most of the learning, in my opinion, happens from student to student. So not so much the teacher nor the workshops but more that the students are teachers to each other […]*"
>
> S6: "*Maybe the lack of support really pushed us to learn group work for example. I mean not lack of support but the thing that we were free to do whatever we want, so whatever decision you make has a great impact on the project […]*"
>
> Later in the same interview:
>
> "*[…] when you feel the need to then you start to collaborate.*"

Some students mentioned reflection and some specific moments or things that had happened during the course.

> S3: "*[…] the thing is that I really had to reflect all the things a lot. […] Still that [reflection] comes often afterwards, not in the moment.*"
>
> S7: "*So probably from misunderstandings are the most what made me realize that there has to be someone to facilitate.*"

7 Discussion and conclusion

Aalto University was formed as part of the quest for increasing Finland´s competitiveness in the global market taking advantages of a multidisciplinary approach. Aalto Design Factory started to function as the spearhead project and first physical manifestation of Aalto already before the official inauguration of the new university. ADF is a co-creation platform for embracing product development and for experimenting new ideas in teaching and learning. The most central manifestation of the ADF principles in education, the Product Development Project –course has a far longer history than ADF. The PDP –course can be described as a capstone project course that has a strong base in interdisciplinary teamwork and is done in collaboration with sponsoring companies who provide real life challenges for student team to solve. The ADF concept has been gathering interest globally as well and a network has been created for supporting better learning. It seems that for implementing a new design factory in an interested institute is to start a PDP-style is a typical step. For that purpose as well as for the PDP´s own future development this thesis aims to provide insight into the PDP and explore possible directions for the future of the course.

The research questions of this thesis were the following:

I. What is the state-of-the-art understanding of the present-day skills and characteristics of an expert product designer?

II. What kind of learning outcomes and skills development from the Product Development Project –course manifests in student retrospectives?

III. What implications do these RQ1 & RQ2) have for the possible future developments of the Product Development Project –course?

Additional and more practical goals for this thesis were to contribute to new uprising design factories by documenting and creating a rich and broad view of the PDP -course in that case that they are interested in initiating their own course.

The research was conducted as a qualitative investigation, including thematic semi-structured interviews with students who had completed the course as well as with the responsible teacher. These were done for exploring the learning outcomes, experiences and for documentation purposes. A literature review was completed in exploration of state-of-art understanding of what an expert product designer embodies as skills and characteristics. In addition teaching approaches related to PDP –stype course were investigated for insight on their usage in this context.

For exploring research question I, a literature review was conducted in related themes. The review was done one two main parts. First the main qualities of a professional worker were looked into. There are several terms used for such non-domain specific skills, such as soft skills and working life skills. The term that is used in this thesis is professional skills. Main skills and competencies identified are displayed in figure 13. Across different sources four main themes were identified: communication skills, team working skills, personal competencies and knowledge and information management.

Secondly the focus was on the design expertise and skills. There were five main themes that were identified: design cognition, communication skills, experience, mindset and personality, and finally designing in a team, also visualized in figure 13.

In the search of answering research question 2 student interviews were conducted. The interview results are visualized in figure 13. The in-depth depictions of the PDP -course can be found in chapter 5. For further exploration the intended learning outcomes have been gathered through official sources as well as interviewing the responsible teacher. The visualization for the intended learning outcomes may be found in figure 13.

For creating an understanding of the possible conclusions research question 3 a compilation of all the three illustrations has been created, it can be found in the appendix 3 as well as in figure 13. When studying these three different representations some differences may be found. The resulting recommendations are tentative and put forth in a suggestive manner for the development of the PDP –course. It ought to be considered that while reading these tentative suggestions and ideas the interview results should be considered with the idea of "absence of evidence does not equal to evidence of absence". Thus meaning that when something does not come up in the interview results it does not necessarily mean that students do not get acquainted with that specific topic, it might however suggest that that topic just is not in the core of the course for students or that they are unable to realize or verbalize their learning.

What resolution can be suggested now taking all the three illustrations into considerations and comparing them against each other? Based on the reflection of the three illustrations some future development suggestions can tentatively be made.

Similarities

First drawing the attention to matching the intended learning outcomes and interview results and whether there is a resonation to be found. Simply said the answer is ´yes, they resonate´. All together this leads to a conclusion that the course seems to work nicely and students seem to learn things that they are intended to learn. Students find teamwork and communication to be very important. Project management rises as a topic that all students had comments about. In the PDP –context a light statement that no matter the team or the project each student most probably learns something about teamwork and communication as shown in the interview results both which are considered as key professional skills (c.f Shuman et al., Crawley et al., 2007) and also something of project management which is part of the intended learning outcomes.

Differencies

Some differences are evident between the skills found in the intended learning outcomes and in the interview results. Experience of completing a project is a given result even if not explicitly by the interviewees, based on the fact that those students did complete the PDP –course and thus did complete the project.

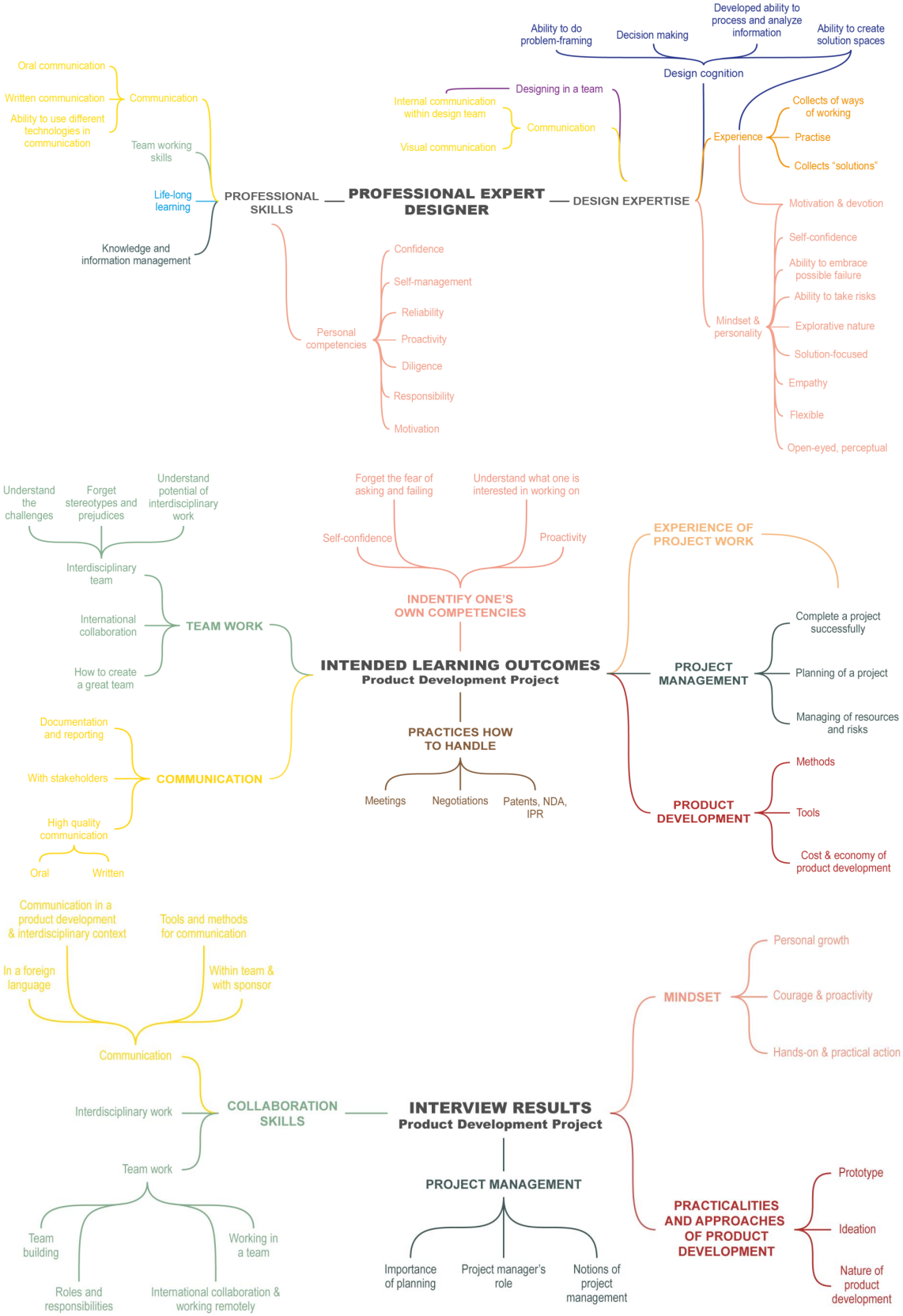

Figure 13 Illustrations of results combined

Evidences of students commenting on practices how to handle negotiations, meetings, patent and NDA´s were not found, neither implicitly or explicitly. Based on that, it could be stated that it is either not very important for the students or not explicitly present for students as an intended learning outcome.

Another interesting observation can be found – the difference of product development methods and tools between the intended learning outcomes and interview results. Interview results exhibit fairly little weight on this topic. It could be challenged that since the PDP –course is only one course in a larger educational module of product development are these product development methods and tools in the core of PDP? Product development cost and economy is also stated as one of the intended learning outcome and it did not explicitly come up at all. Either some structures for increasing the meaning of costs and economy in product development in the PDP –course could be created or leave that out of the intended learning outcomes as not an important topic.

Design expertise

Regarding design expertise rather little similarities were explicitly stated in the student interviews nor is design cognition explicitly stated in the intended learning outcomes. However this is what makes a person a designer – the cognitive processes of design (c.f. Schön, 1983, Cross, 2011, Lawson & Dorst, 2009). As presented in figure 13 design cognition includes problem-framing, ability to create solution spaces, making decisions and processing information in design context – all skills and abilities that are crucial for designing. As presented by Schön (1983) this is also something that is coachable but not teachable. Students would likely benefit of coaching in order to develop these abilities. Thus a suggestion for the development of PDP –course is that in order to give better possibilities for students to actually grow and develop as an expert designer is to coach their design cognition. Some structures exist in the PDP that use coaching, for example facilitated feedback session that is aimed for teamwork. Perhaps something similar might be worth trying out for developing design cognition.

Design expertise entails experience of design which is something that students get when completing the PDP –course as well as they will be working in a design team during the project. However students often stated that they knew when teamwork did not work and they had no idea how work in a more collaborative way and as suggested by Kleinsmann et al.(2012) a collaborative tentative communication is one factor influencing design teamwork and Cross (2011) also brings out the necessity of understanding the roles and one´s own contribution for the project. The PDP –course without a doubt is a good chance to practice but would it be possible to enhance the collaborative manner of working and communicating? Some structures already exist such as the facilitated feedback session for teamwork. However even the fact that the PDP –course exists provides an opportunity to develop communication skills with students from other fields of studies.

Related to understanding one´s role in a team and identifying one´s own capabilities as stated in the intended learning outcomes, similar topic is presented in design expertise – mindset and personality. The same topic can be observer throughout the illustrations of the results in figure 13. In the illustration of a professional expert designer personal competencies and personality and mindset are both important (c.f. McQuiad & Lindsey, 2005, Cross, 2011, Lawson & Dorst, 2009). In the intended learning outcomes it is also emphasized quite a bit. However in the interview results this category is rather small and limited. Litzinger et al. (2011) suggest that it would be important for the students to understand what qualities they will be need in the future

ought to be clearly communicated with them. The personal growth and competencies is a result of understanding and reflecting individually and understanding what is an expert designer like and into what direction one should grow. This relates to becoming a professional expert designer and understanding what is it to be that – not only the actions that they do (Seely Brown & Adler, 2008). On the other hand it is still a valuable outcome to give encouragement, good attitude and a possibility for personal growth, but it is not a same thing with identifying one´s own competencies. The suggestion for development is that individual reflection could be one way of increasing the awareness of one´s own capabilities and mindset and personality qualities of an expert designer.

Even when design thinking is considered as an unclearly defined term, it is still considered as an important skill for 21st century design (Razzouk & Shute, 2012). Design thinking is not explicitly seen in the intended learning outcomes or in the interview results. It does not have to be in the core of the PDP –course but it could be communicated in the course for example through the example of IDEO, which enhances the user- and human-centeredness in design process as well as multidisciplinary action (Brown, 2009). Then the term at least would be familiar.

Learning

Turning the attention to teaching and learning. The PDP –course falls according to these findings under the descriptions of PBL, PjBL and DBL but does not seem to follow directly either of them (c.f. de Graaff & Kolmos, 2007, Savin-Baden, 2000, 2007, Goméz Puentes, 2013) . Regardless of not following strictly any of the presented teaching approaches the course seems to provide mostly that kind of results as it intended and thus may be stated to be successful.

Regarding course practicalities that were studied lightly in the interviews, some very light tentative conclusions can be drawn. It cannot be stated that the course components from the course book to the lectures are not useful nor helpful but this data does however suggest that they are not the “beef” of the PDP course. They are used if needed and if remembered. The PDP is not meant to give the theoretical things on product development but to give the opportunity to explore and practice as proper for a capstone course (c.f. Froyd et al.,2012). The ADF environment and its meaning for the students can be observed through the amount of comments in the interviews – support provided by the staff, the sponsor and ADF facilities were widely recognized as a functioning and important factor – far more important than any of the other components such as books, lectures or other events. These results resonate with the teaching and learning concepts presented in chapter 4 in which the learning atmosphere and social learning were presented.

Kolb´s ELT is most probably present in the PDP –course, especially the active experimentation concrete experience –parts. Reflection is left to one´s own account as well as abstract conceptualization – both stages that are important for developing new knowledge (Tynjälä, 1997). Schön (1983) suggests especially in the design context coaching and reflecting with an expert. Tynjälä (1997) also suggests that the concept of learning should be defined anew for learners who are learning by doing – maybe communicating that to the future PDP students could enhance understanding of how learning happens in the PDP –course?

Overall impression and future research suggestions

In order to become a far more advanced product designer than other graduates The PDP could be an incredible opportunity to fast track learning if some kind of structures for example regarding reflection and coaching were present. The overall impression of the PDP –course is that it is successful and does deliver good results. However professional skills seem to be the stronger learning outcome than of design expertise. It can be thought as both a good and bad thing depending on what is the expectation. If professional skills are the main point of the PDP –course then they could be enhanced with increased individual reflection. If design expertise ought to be in the core of the PDP –course then something definitely should be done for increasing the awareness and reflection of design expertise.

For future studies would be interesting to investigate has the PDP in fact had some impact on its students´ employability or success in the working life. This thesis opened the conversation of some learning outcomes acknowledged by the students and some aspects of the concept of employability. However it does not answer the question what role PDP has later on played in its alumni´ life. Another future study could also be to investigate what the students actually learn of product development and does PDP provide give opportunities for design cognition to develop.

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Appendix 1 – The student interview outline

11.6.2013 Haastattelupohja

Kurssi yleisesti

- Kurssikokemus
  - haasteet
- PDP vs. muut kurssit

Mitä opit?

- Mitä
- Mikä auttaa tulevaisuudessa?

Critical Incidents

- Hyvät
- Huonot

Tekijät

- Prosessi
- Kurssin käytännön järjestelyt
  - Tilat
  - Henkilökunta
    - Toiminta
    - tuki

luennot/materiaalit

- Ongelmat
  - milloin
- Hyvää ja kehitettävää
- Jotain muuta?

Appendix 2 - The responsible teacher´s interview outline

11.6.2013 Haastattelupohja

Kurssi yleisesti

- Kuinka kauan pidetty
- Opiskelijamäärät
- Taustat

Oppimistavoitteet

- Listaus
- Tärkeysjärjestys
- Miten näihin päästään
- Työelämän vaatimukset
- Tarjoaako kurssi jotain muuta

Kurssin järjestelyt ja käytännöt

- Rakenne
- Prosessi
- Tilat
- Henkilökuntaresurssit
- Tavat

Critical Incidents

- Hyvät
- Huonot

Appendix 3 – The illustrations of professional expert designer, intended learning outcomes and interview results